Metal Art Crafts

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To my wife

HETTY

PREFACE

Metal Art Crafts is a book of materials, tools, processes, and projects designed for the use of those who are interested in exploring the various areas of metalcraft. Each individual material used in the craft shop is described in detail including such pertinent information which it is necessary to know when selecting and ordering the materials needed. All tools common to metalcraft work are illustrated and supplemented with an explanation and description of the particular function of each. The object of this section is to acquaint the reader with the proper use and nomenclature of each hand and machine tool used in metalcraft work. The section on processes and operations has been organized in such a manner that the metal-worker can look up the directions for any particular phase of metalcraft in which he may be interested.

Twenty-two projects have been grouped in the final chapter, each including a drawing and picture of the finished article and, on the opposite page, a bill of material and the step-by-step procedure necessary for the construction of the project. Projects have been arranged in groups involving the various phases of metalcraft work. For this reason, the beginner need not necessarily start with project number one. It is suggested, however, that the beginner select a basic project before attempting one which may be too difficult. Before any project in chapter four is attempted, reference should be made to the more detailed description of the materials, tools, and processes as described in the previous chapters.

In preparing this book, the author has enlisted the assistance of a number of former students who are training to be either industrial arts or craft teachers. To these students he wishes to express his sincere appreciation. My thanks also to Professor Ray E. Haines and Professor John V. Adams, of the Department of Vocational Education, New York University, who generously reviewed portions of the manuscript.

J. G. M.

Baldwin, N. Y.

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Chapter I

METALCRAFT MATERIALS AND SUPPLIES

Copper.

Copper is the most common metal used in the metalcraft shop. Since it is soft, very ductile, and malleable, it can be used for work which requires stretching by hammering and bending. Copper has a reddish color, will take a fine polish, and reacts when treated with various chemicals, producing various colored effects on its surface.

The most common form in which copper is used in the metalcraft shop is in sheets. It may also be obtained in the form of rods, bars, tubes, and wire. A sheet measuring 30″ x 60″ is a common size and is recommended for a shop which is equipped with a 30″ squaring shear. Some supply houses furnish copper in coils 12″ or 18″ wide. These sizes are more easily handled when no squaring shear is available.

The thickness of copper is gaged by the Brown & Sharpe gage. This is a system of gage numbers, each indicating a definite thickness in thousandths of an inch. The B & S gage numbers range from Nos. 0000 to 40. The larger the gage number the less the thickness of the metal. A No. 14 gage sheet is about 1/16″ thick. When ordering copper it is well to specify the B & S gage number and the thickness of the sheet in thousandths of an inch in order to eliminate errors in the use of other than B & S standard gages. The price of copper sheets is figured by the pound. It is therefore necessary to know the weight of the sheet when ordering so that the net price can be determined. The following table is useful in checking the gage and weight of sheet steel, iron, brass, and copper.

Sheet copper is frequently designated by the weight in ounces per square foot instead of the B & S gage number. The use of this system eliminates the necessity of measuring and weighing the copper. The practice of using various gages to measure sheet metals makes it imperative to designate the gage being used or the thickness in thousandths.

The most suitable sheet copper for use in metalcraft work is *cold-rolled, annealed.* Cold-rolled sheets have a bright smooth surface and are not likely to be pitted or contain deep scratches. Annealed stock is soft

COMPARATIVE THICKNESS OF COPPER SOLD BY WEIGHT SHOWING NEAREST B & S AND STUBS GAGE NUMBER

Weight per Sq. Ft. (Ounces)	Weight per Sq. Ft. (Pounds)	Thickness (Inches)	Nearest Gage Number B & S	Nearest Gage Number Stubs	Nearest Fraction
	16	.3456	00	00	11/32
	15	.3240	0	0	21/64
	14	.3024	1	1	19/64
	13	.2808	1	2	9/32
	12	.2592	2	3	1/4
	11	.2376	3	4	15/64
	10	.2160	4	5	7/32
	9½	.2052	4	6	13/64
	9	.1944	4	6	
	8½	.1836	5	7	3/16
	8	.1728	5	8	11/64
	7½	.1620	6	8	
	7	.1512	7	9	5/32
	6½	.1404	7	10	9/64
	6	.1296	8	10	1/8
	5½	.1188	9	11	
80	5	.1080	10	12	7/64
72	4½	.0972	10	13	3/32
64	4	.0864	11	14	
56	3½	.0756	13	15	5/64
48	3	.0648	14	16	1/16
44	2¾	.0594	15	17	
40	2½	.0540	15	17	
36	2¼	.0486	16	18	3/64
32	2	.0432	17	19	
28	1¾	.0378	19	20	
24	1½	.0324	20	21	1/32
20	1¼	.0270	21	22	
18	1⅛	.0243	22	23	
16	1	.0216	23	24	
14	⅞	.0189	25	26	
12	¾	.0162	26	27	
10	⅝	.0135	27	29	
8	½	.0108	29	31	
6	⅜	.0081	32	33	
4	¼	.0054	35	35	
2	⅛	.0027			

and can be bent and formed into shape directly without the necessity of annealing before the work is started. Sheets should be protected in storage so that the surface does not become scored. Large sheets may be cut on the squaring shear to convenient sizes to fit on a shelf or bin. Coil stock may be stored on a shelf and cut from the coil as it is used.

Brass and Bronze.

Common brass is a copper-zinc alloy containing one-third zinc and two-thirds copper. Bronze is a copper-tin alloy containing 90 per cent copper and 10 per cent tin. Both tin and zinc are commonly used in the same alloy so that we have an almost infinite variety of copper-tin zinc alloys with varying percentages of each metal. All these bronzes contain at least 50 per cent copper.

Brass varies in color from a low brass, which contains a high percentage of copper (about 85 per cent) and has a reddish color, to a high brass, which has a high zinc content (about 35 per cent) and is much lighter in color. Brass is harder and not as malleable as copper and is therefore not as easy to work.

Bronze is usually more copper-colored than brass; however, this is not always the determining factor in identification. Bronze alloys are much harder and more brittle than brass and for this reason are of little use in the craft shop. Ornaments and *findings* are sometimes cast of bronze and may be purchased from a supply house for use as needed.

Common brass is obtainable in rods, bars, flats, tubes, wire, and sheets. Sheet brass is available in the same size sheets as copper. As with copper, the thickness of brass and bronze sheets is generally designated by the B & S gage number. Brass, finished by annealing, is designated thus:

Light anneal or blued
Drawing anneal or blued soft
Soft drawing or soft

Brass bar, rod, and strip is purchased by giving the dimensions of the particular shape required and the length. Brass wire is measured with the B & S gage and may be bought either by weight or by the length.

German Silver.

German silver, or *nickel silver* as it is sometimes called, is an alloy resembling silver. Its composition is generally 60 per cent copper, 20 per cent zinc, and 20 per cent nickel however, various alloys will contain more

or less nickel. German silver has much the same physical properties as brass and is sold in coils 6″ or 12″ wide. Like brass and copper, the most common thickness gage used to designate German silver is the B & S gage. When ordering, order either hard or annealed depending on the use to which the metal is to be put.

Zinc Based Alloys.

There are many alloys on the market which contain varying amounts of zinc, aluminum, copper, and tin. Alloys containing zinc as the major alloying element are known as zinc alloys. These alloys, like the copper alloys, are almost infinite in number. Zinc alloy sheets are sold for metal-craft work under various trade names. The color of zinc alloy resembles pewter and may be substituted for this metal in certain elementary work; however, its quality is inferior to pewter and therefore, if possible, it should not be used as a substitute. Zinc alloy, however, in the form of pigs weighing about five pounds, makes a good metal for melting and casting. Its melting temperature is about 800° F. and therefore can be easily melted in a three-burner gas furnace. It takes a high polish but will tarnish quickly if its surface is not lacquered.

Aluminum.

In the past century, the process of refining aluminum has been so rapidly developed that the price has gradually decreased from $5.45 per pound in 1852 to a price today of less than twenty cents per pound. Aluminum is one of the lightest metals in common use, weighing about one-third as much as iron. In its pure state, it is soft and ductile. It cuts and files easily and will bend without fracture. Aluminum resists corrosive action from the atmosphere and therefore retains a bright finish without other protection.

The fact that aluminum will not solder as easily as other metals will limit its use in art metal work. It is sold in sheets and coils of various thickness, gaged by the B & S gage. Its price per pound is less than copper and, since it is such a light metal, it is economical to use in the craft shop. Many shapes other than sheets may be obtained, such as bars, rods, tubes, plates, and many extruded shapes.

Sterling Silver.

Sterling silver is an alloy containing 92½ per cent silver and 7½ per cent copper. Sterling has a whitish color, solders readily with either hard

or soft solder and can be worked with the various metal tools as easily as copper. Sterling silver may be purchased in sheets 6″ wide. The gage most common is the B & S gage. Small pieces of this metal may be purchased cut to the desired dimensions.

Due to the relatively high cost of sterling silver, one must limit its use to small ornaments. The beginner may learn all the metalcraft techniques by using less expensive metals.

Pewter.

Pewter, or Britannia metal is an alloy of tin, antimony, and copper. Most present-day pewters contain approximately 90 per cent tin, about 1.5 per cent copper and the balance antimony. Its melting point is approximately 430° F., depending upon the manufacturer.

Pewter is a softer and heavier metal than the other metals used in metalcrafts. Pewter will resist corrosion almost indefinitely. Contrary to common opinion, pewter has a high resistance to the action of chemicals contained in foods and drinks. Utensils may be used with foods without any fear of poison.

Pewter may be purchased in sheets 18″ x 24″ or in ready-cut discs in diameters from 3″ to 12″. The thickness of pewter is gaged by the B & S gage. Pigs may be purchased for casting.

Steels.

Mild steel is an inexpensive material for use in the metalcraft shop. It is a steel which is malleable and ductile and therefore can be worked into various shapes while cold without fracture.

Band iron, or strap iron, is a form of mild steel which may be purchased in sizes ranging from straps as thin as 1/16″ and as narrow as 1/4″. This metal has a dull black oxide finish and is quite ductile and comparatively easy to bend without heating. This form of iron is used to make so-called "wrought iron" articles. It may be drilled, filed and sawed easily, and can be bent upon itself without cracking.

Black iron sheets are a form of mild steel that has the same physical qualities as band iron. Its thickness is gaged by the U.S. Standard sheet iron and steel gage (see table on p. 11) and it is manufactured in standard sheets from 30″ to 36″ wide and in lengths up to 8′. Black iron is used in conjunction with band iron for projects of "wrought iron".

Tin plate is a sheet of black iron with a very thin coating of tin on each side. Tin plate is furnished in sheets measuring 20″ x 28″ and in thick-

nesses as measured by the tin plate gage (see table on p. 11). It is interesting to note that it has been standard practice to use about 1½ lbs. of tin to 100 lbs. of iron. The chief quality of tin plate is the brightness of its surface which is a result of the plating. This process gives the metal a corrosion-resistant finish. The chief use of the metal is in the manufacture of tin cans and kitchen utensils. It bends, flanges, burrs and solders easily but, if heated above the melting point of tin, it will lose its plating.

Tool Steel.

Steel with a high carbon content which can be hardened and tempered is known as *tool* steel. This steel cannot be distinguished from iron or mild steel by its outward appearance; however, a piece of tool steel may be tested by grinding. If the grinding sparks explode at the ends, then the piece being tested is tool steel. Compare the sparks from a piece of mild steel with a piece which is known to be tool steel and observe the difference in the sparks. The best means of positive identification, however, is to heat the steel to a "cherry" red and quench it in water. If the piece hardens, it is tool steel; if not, it must be some form of mild steel. Tool steel is made in bars of many different cross-sectional shapes. Hexagonal, octagonal, and round bars are especially useful for making chisels and chasing tools. Tool steel is usually sold by the pound. It is a good policy to paint an identifying color on the surface of the tool steel when it comes in the shop. This precaution will prevent errors in substituting other steels for tool steel.

Solder.

The various alloys produced from tin and lead are usually known as soft solders. The alloy consisting of 50 per cent tin and 50 per cent lead is known as common solder. This solder melts at about 430° F. and is commonly sold in the form of a bar or wire. Common wire solder is manufactured either with a core which contains the flux or as a solid wire. The two most common cored solders are acid core and rosin core. These flux-cored solders are handy for certain jobs; however, they are not suitable, for the most part, in the metalcraft shop.

Pewter solder is a soft solder with a lower melting point than common half-and-half solder. This solder is made of 60 per cent tin, 40 per cent lead, and melts at approximately 340° F. A still lower melting point may be obtained with a 63-37 tin-lead alloy solder. The 60-40 is the best type

to stock when only one solder is to be used on the pewter. It is sometimes necessary when soldering pewter to use two or more solders with different melting points in order not to melt one joint when soldering the next. This method of soldering is known as successive soldering. For this purpose one may purchase a tin-lead-bismuth solder which has a still lower melting point.

Solders called *hard solders* or silver solders are stronger and have a higher melting point. These solders contain various metals in their alloys. Brazing rod is a common form of hard solder which is an alloy of copper and zinc. Silver solders are high in tin content and contain some silver. A special solder is available for soldering aluminum. This solder comes with the correct flux provided. Care should be taken when using this solder to follow the directions carefully as success will depend on the correct procedure.

Flux.

The least film of grease, dirt or oxide on the metal to be soldered will prevent the solder from sticking. Therefore, the surface must be cleaned and coated with some substance which will reduce the oxide. For this purpose, a soldering flux is used. The most common one is zinc chloride. This is made by allowing a small amount of muriatic acid to dissolve all the zinc that it will, and then straining, and diluting with equal parts of water. The selection of the proper flux depends on the material to be soldered. Fluxes which work well on one metal may have no effect on another. Borax is used almost universally when silver-soldering all metals. The following is a table of common fluxes used when soft-soldering:

FLUXES USED FOR VARIOUS METALS

Material	*Flux*
Electrical work	Rosin
Tin plate	Ammonium chloride (Sal Ammoniac)
Black iron Galvanized iron	Zinc chloride (Killed HCL)
Copper Brass	Rosin or ammonium chloride
Aluminum Stainless steel	Use special solder and flux provided with solder
Pewter	10 drops of HCL added to 1 oz. glycerin
German silver	Rosin or ammonium chloride

Iron Binding Wire.

Iron wire for binding together work that is to be soldered is essential in the metalcraft shop. It is available annealed in spools weighing either 1 or 4 oz. Wire sizes are gaged by the B & S wire gage (see table p. 11).

Round head, or button head, rivets are obtainable in fractional diameters from 1/8" to 7/16" and in varying lengths and are sold by the pound. Countersunk head iron rivets are available in the same sizes. Copper, brass, bronze, Allegheny metal, and other special types of rivets can be purchased in sizes as noted in manufacturers' catalogs.

Flat head copper rivets and burrs are available in seven different sizes, diameters ranging from No. 7 to No. 13 and lengths from 1/4" to 1 1/2".

Tinner's rivets are specified by the weight per thousand. For example, a 12-oz. rivet means that 1000 rivets weigh approximately 12 oz., or an 8-lb. rivet means that 1000 of these rivets weigh approximately 8 lbs. The size of the rivet varies from the 4 oz., which is 0.070" in diameter and 1/8" in length, to the 16 lb., which is 0.293" in diameter and 17/32" in length.

Finishing Materials.

Many materials are used to polish and prevent oxidation on a piece of metal. These materials are classified as finishing materials.

Steel wool is used to clean metal parts before applying acid-resist and is used to remove deep scratches from the metal before the piece is buffed. Steel wool is packaged in 1-lb. rolls and is available in several grades. Three good sizes to stock for all-round use are No. 000 extra fine, No. 0 medium, and No. 1 coarse. Steel wool that is packaged in pad form eliminates pulling the wool apart and is more economical.

Pumice powder is an abrasive used in scrubbing and cleaning metal. It is a white powder which is sold in 1-lb. packages in various coarsenesses. Fine, medium, and coarse grades are all useful in the craft shop. Pumice is also used to obtain various satin finishes on metal.

Emery is a rapid-cutting abrasive which is made from natural stone. It is available in the form of powder to be used much the same as pumice and also with a paper or cloth backing. Emery is also put up in the form of a paste stick for use as an abrasive in polishing on the buffing machine. The grain of emery is graded much the same as sandpaper: No. 000 being a fine grain, No. 1/2 medium, and No. 2 a coarse grain. The sheets of paper or cloth measure 9" x 11" and are sold by the quire. Emery paste

sticks for buffing come only in one grit and are used in the ruffing operation only. Dry emery powders are sold by the pound.

Buffing compounds, as the name implies, are abrasives used on buffs for the removal of scratches and other minor imperfections from the surface of metal or other materials in order to produce a high luster on the finished piece. In addition to emery paste, there are three common kinds of buffing compounds which are necessary in order to produce the highest possible luster. *White diamond dust* compound is used to "cut down" and polish practically all of the metals used in the metalcraft shop. This compound is especially efficient on aluminum and pewter. *Tripoli* is a reddish-brick-colored compound which is the most widely used polishing agent for "cutting down" brass, copper, aluminum, German silver, and sterling. *Jeweler's rouge* is a red composition used as a final polishing agent. Rouge is different from other polishing compounds in that it does not "cut down" the stock but it burnishes the metal surface. For this reason, jeweler's rouge is especially useful in polishing articles made of silver and gold.

Liver of sulphur is a chemical used to obtain an oxidized surface on metals. It is sold by the pound. The large chunks are broken up and dissolved in water for use as it is needed.

Wax is used as a protection on the surface of the metal to retard tarnishing. Ordinary floor paste wax is a good type to stock. This can be obtained in 1-lb. cans.

Lacquer is used to prevent tarnishing of the surface of polished metal objects. Metal parts which are lacquered will withstand a good deal of handling and still retain their original luster. Clear metal lacquer is sold by the gallon or in smaller quantities. When ordering lacquer, include *lacquer thinner.* This is the solvent for lacquer and may be used to thin the lacquer, to clean the brush, and to clean the metal before the lacquer is applied.

Etching Equipment.

Material used in the metalcraft shop for preparing the metal for etching and etching a design in the metal may be classified under two headings: (a) Those materials used to resist the acid, and (b) etching mordants, or acids.

Black asphaltum is the most common acid-resist used in the etching process. This varnish is sold in cans by the pint or quart. It is quite often too thick to use as it comes from the can, and therefore may need to be thinned with turpentine to the consistency required. There are a number

of commercial preparations on the market which may be used in place of asphaltum. The printer uses a resist called *stopping-out varnish* which works well in metalcraft work when the design is of unusually fine lines.

Nitric acid, used for etching copper, brass, German silver and many other metals, is sold at a chemical supply house or may be obtained in small quantities at the local drug store. It is usually obtained commercially concentrated in bottles of about 7 lbs.

Sulphuric acid, used to make up a pickling solution, may also be obtained as above.

Hydrochloric acid is used to make up fluxes for soldering various metals. This acid also may be obtained at a drug store; however, because of its limited use, it should be bought only in small quantities.

GAUGES IN USE IN THE UNITED STATES

Gauge No.	Washburn & Moen Steel Wire	American or Brown & Sharpe	U. S. Standard Sheet Iron & Steel	Birmingham or Stubbs Iron Wire and Sheets	Morse Twist Drill and Steel Wire	Wood and Machine Screws	Tin Plate	Zinc Plate
0000000	.490		.500					
000000	.4625		.469					
00000	.4305		.438					
0000	.3938	.460	.406	.454				
000	.3625	.4096	.375	.425		.032		
00	.3310	.3648	.344	.380		.045		
0	.3065	.3249	.313	.340		.058		
1	.2830	.2893	.281	.300	.228	.071		.002
2	.2625	.2576	.266	.284	.221	.084		.004
3	.2437	.2294	.250	.259	.213	.097		.006
4	.2253	.2043	.234	.238	.209	.110		.008
5	.2070	.1819	.219	.220	.2055	.124		.010
6	.1920	.1620	.203	.203	.2040	.137		.012
7	.1770	.1443	.177	.180	.2010	.150		.014
8	.1620	.1285	.172	.165	.1990	.163		.016
9	.1483	.1144	.156	.148	.1960	.176		.018
10	.1350	.1019	.141	.134	.1935	.189		.020
11	.1205	.0907	.125	.120	.1910	.203		.024
12	.1055	.0808	.109	.109	.1890	.216		.028
13	.0915	.0720	.094	.095	.1850	.229		.032
14	.0800	.0641	.078	.083	.1820	.242		.036
15	.0720	.0571	.070	.072	.1800	.255		.040
16	.0625	.0508	.0625	.065	.1770	.268		.045
17	.0540	.0453	.0563	.058	.1730	.282		.050
18	.0475	.0403	.0500	.049	.1695	.295		.055
19	.0410	.0359	.0438	.042	.1660	.308		.060
20	.0348	.0320	.0375	.035	.1610	.321		.070
21	.0317	.0285	.0344	.032	.1590	.334		.080
22	.0286	.0254	.0313	.028	.1570	.347		.090
23	.0258	.0226	.0281	.025	.1540	.360		.100
24	.0230	.0201	.0250	.022	.1520	.374	1XXXXX	.125
25	.0204	.0179	.0219	.020	.1495	.387	1XXXX	.250
26	.0181	.0159	.0188	.018	.1470	.400	1XXX	.375
27	.0173	.0142	.0172	.016	.1440	.413	1XX	.500
28	.0162	.0126	.0156	.014	.1403	.426	1XL–1X	1.000
29	.0150	.0113	.0141	.013	.1360	.439		
30	.0140	.0100	.0125	.012	.1285	.453	1C	
31	.0132	.0089	.0109	.010	.1200	.466	90 lbs. 95 lbs.	
32	.0128	.0079	.0101	.009	.1150	.479	85 lbs.	
33	.0118	.0071	.0094	.008	.1130	.492	80 "	
34	.0104	.0063	.0086	.007	.1110	.505	75 "	
35	.0095	.0056	.0078	.005	.1100	.518	65 lbs. 70 lbs.	
36	.0090	.0050	.0070	.004	.1065	.532		
37	.0085	.0044	.0066		.1040	.545	60 lbs.	
38	.0080	.0040	.0063		.1015	.558	55 "	
39	.0075	.0035			.0995	.571		
40	.0070	.0031			.0980	.584		
41	.0066				.0960	.597		
42	.0062				.0935	.611		
43	.0060				.0890	.624		
44	.0058				.0860	.637		
45	.0055				.0820	.650		
46	.0052				.0810	.663		
47	.0050				.0785	.676		
48	.0048				.0760	.690		
49	.0046				.0730	.703		
50	.0044				.0700	.716		

TINNER'S RIVETS

Size	Dimensions	
Weight per 1000 lbs. and oz.	Length	Diameter
6 oz.	9/64"	.080
8	5/32	.090
10	11/64	.094
12	3/16	.101
14	3/16	.109
1 lb.	13/64	.115
1¼	7/32	.120
1½	15/64	.125
2	17/64	.140
2½	9/32	.147

DECIMAL EQUIVALENTS

1/64—.015625	17/64—.265625	33/64—.515625	49/64—.765625
1/32—.031250	9/32—.281250	17/32—.531250	25/32—.781250
3/64—.046875	19/64—.296875	35/64—.546875	51/64—.796875
1/16—.062500	5/16—.312500	9/16—.562500	13/16—.812500
5/64—.078125	21/64—.328125	37/64—.578125	53/64—.828125
3/32—.093750	11/32—.343750	19/32—.593750	27/32—.843750
7/64—.109375	23/64—.359375	39/64—.609375	55/64—.859375
1/8—.125000	3/8—.375000	5/8—.625000	7/8—.875000
9/64—.140625	25/64—.390625	41/64—.640625	57/64—.890625
5/32—.156250	13/32—.406250	21/32—.656250	29/32—.906250
11/64—.171875	27/64—.421875	43/64—.671875	59/64—.921875
3/16—.187500	7/16—.437500	11/16—.687500	15/16—.937500
13/64—.203125	29/64—.453125	45/64—.703125	61/64—.953125
7/32—.218750	15/32—.468750	23/32—.718750	31/32—.968750
15/64—.234375	31/64—.484375	47/64—.734375	63/64—.984375
¼—.250000	½—.500000	¾—.750000	1—1.000000

MELTING POINTS OF ALLOYS OF TIN AND LEAD

Parts Tin	Parts Lead	Melting Point in ° F.
3	1	367°
4	1	372°
5	1	381°
2	1	385°
1	1 (half and half)	466°
1	0 (pure tin)	475°
1	3	552°
0	1 (pure lead)	618°

Chapter II

TOOLS USED IN THE METALCRAFTS

Marking, Measuring and Layout Tools.

The *scratch awl,* or scriber, is a sharp-pointed tool made of tool steel. It has a hardened point so that it can be used to mark lines on the surface of metals. This tool is made in a large variety of sizes and shapes. It may have a handle made of wood, plastic, or metal, or it may be of the double-pointed type without a handle.

Center punches are made from tool steel. They are used to make marks or dents in the surface of the metal. A dent may be used to give an accurate starting point when drilling a hole or to locate a center accurately before using the dividers in laying out an arc or a circle. If the center punch is used to locate the center of a circle or arc, be sure that the mark does not injure the surface of a piece of metal which is later to be polished. The metal that is to be punched should be laid on an anvil or a block of smooth metal in order that the metal can be marked with a minimum of deforming. Center punches for use in the craft shop should be about 4″ long with a point about 3/32″ in diameter. The point is sharpened on the grindstone at an angle of about 90 degrees.

The *prick punch* is a tool similar to the center punch except the point is ground at an angle of 60 rather than 90 degrees, and it is generally used for lighter work.

The *scale,* or *rule,* should be made of spring-tempered steel and is usually provided with graduations in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch. The length of the scale should be at least 6″ for most work; however, the size of the projects to be made may require a longer one.

A *steel square* is an essential item in the metalcraft shop. It is used to lay out lines at right angles to an edge on the metal. There are many kinds of squares on the market; however, the one that is suitable for most purposes is the 12″ *combination square.* This square has an adjustable head and may be used as a marking gage to mark a series of lines parallel to an edge on the metal. It is also equipped with a scriber inserted in the handle, and may be used to mark or test angles of 45 degrees. Another type of square

that is handy to have in the shop is the *carpenter's,* or *framing,* square. This square, especially useful with large work since the longer blade is 24″ long, can be used as a long straight-edge in testing and laying out straight lines on metal.

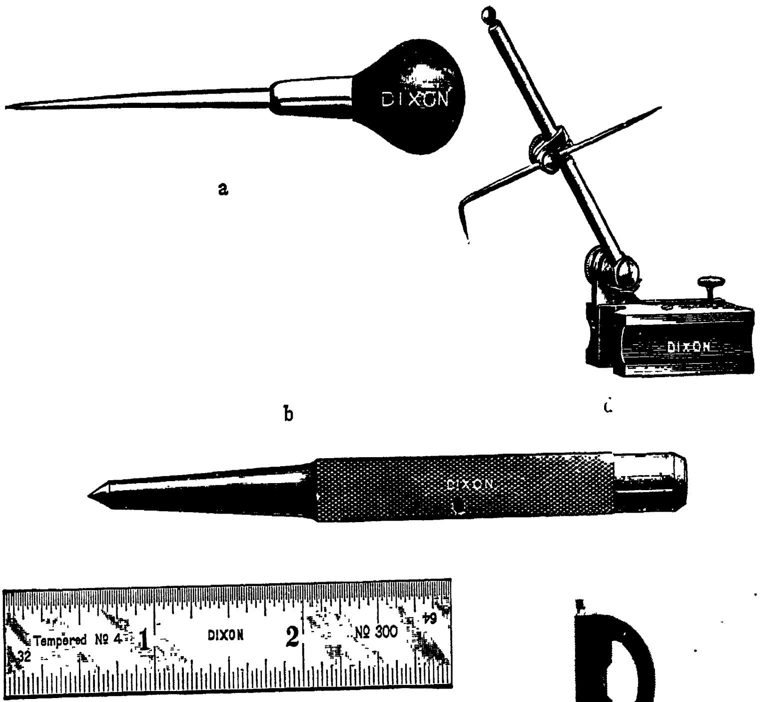
Dividers are instruments employed to lay out arcs of circles or circles on the surface of metal. The dividers may also be used to "step off" spaces of equal length on the metal. Two common types of dividers are the spring and the wing divider. The spring divider can be adjusted more accurately than the wing divider; however, the wing divider is more rigid than the former and therefore is generally preferred when working with the various art metals. Spring dividers may be purchased in 3″, 4″, 5″ or 6″ lengths, whereas the wing divider is usually available in larger sizes. A 6″ divider will make a circle 12″ in diameter.

Calipers are used primarily to measure the diameters of round objects. Spring calipers operate much the same as spring dividers. They are also available in the same sizes as the dividers. There are three kinds of calipers: (a) *outside calipers,* (b) *inside calipers,* and (c) *hermaphrodite calipers.* The outside caliper is used for outside work, whereas the inside caliper is used to measure the diameters of holes, etc. The hermaphrodite caliper is a layout tool, one leg of which is a caliper leg and the other a divider leg. This tool is especially useful in laying out and testing. The inside and outside calipers are available in both the spring and the friction type. The spring type is far superior to the friction type when accuracy is of prime importance; however, when rapid action with a reasonable degree of accuracy is required, the friction type is more easily set.

Surface Gage. The surface gage may be used in conjunction with a surface plate or a flat metal bench-plate. The point or scriber is set at a given height from the base, and the gage is moved about on the plate, marking the given height on a piece of metal. In the metal shop, the surface gage is usually used to "true up" a metal bowl that has been hammered. The surface gage is essentially a toolmaker's tool and therefore is considered to be a precision tool. The use to which the surface gage is put in the metalcraft shop does not require a great deal of accuracy; therefore it is not essential to purchase the best quality. A good size for most work is a gage with a 6″ spindle.

Hammers and mallets.

The hammer and mallet are probably the most important tools in the metalcraft shop. The hammer has many uses. It may be used to hit an-



c

e

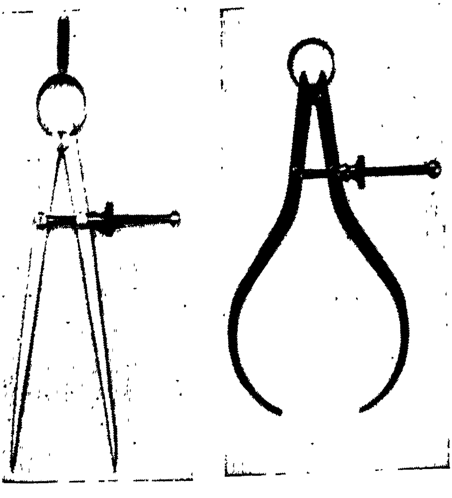


FIG. 1. Measuring and layout tool

a. Scratch awl
b. Center punch
c. Scale
d. Surface gage
e. Combination square
f. Dividers
g. Outside calipers

other tool such as a punch or a chisel or it may be used directly to form or mark the metal. The mallet is used to form or bend the metal. There are hammers and mallets of many forms and shapes. The following are some of the kinds that are used on metalcraft work.

The *ball peen hammer* is a common machinist's hammer. It is made of tool steel. One end of the hammer head is spherical in shape whereas the other end has a face which is slightly convex. This hammer serves as an all-purpose hammer in the craft shop. It may be used to strike other tools such as the cold chisel, chasing tools, or punching tools. The ball end can be used to "head over" rivets or may, if no other hammer is available, be used to peen a piece of metal. These hammers are designated by their weight. Sizes from 8 oz. to 16 oz. are most common.

The *cross peen,* or *riveting,* hammer has a beveled peen at right angles to the handle. This hammer is used especially for riveting. It is generally light in weight and is most commonly used in sizes from 4 oz. to 12 oz.

A hammer especially designed to raise a piece of metal into the shape of a bowl is known as a *raising,* or *forming,* hammer. These hammers have varied forms and shapes depending on the use to which they are put. The lighter hammers are for small work such as spoon raising, whereas the larger ones are for larger pieces of work. Raising hammers have two faces which are convex in shape and whose corners are rounded so that there is a minimum chance of the hammer marking the metal as it is being formed.

The *planishing hammer* is used to remove blemishes from the surface of metal. This hammer may look a good deal like the raising hammer; however, if one inspects its surface, he will notice that the planishing hammer has faces which are polished to a mirror-like surface. This hammer has a limited purpose—producing various bright facets on the surface of finished work. These hammers are made with faces of varied spherical radii. Those with a small radius will produce a small facet on a flat surface, whereas those with a face which has a large radius will produce a large facet on a flat surface. Some planishing hammers have a face which is almost flat. These faces are designed to be used on convex surfaces such as the outside surfaces of a hammered bowl. When using the planishing hammer on flat work, one must place the work on a *planishing block* which is a flat piece of iron or steel that has been ground perfectly smooth and then polished to a mirror-like finish. This block is usually square or rectangular in shape and may be placed on the bench or held in the vise while planishing. Work other than flat work is planished over a stake of the proper shape. The same precautions must be taken to have a highly polished surface on

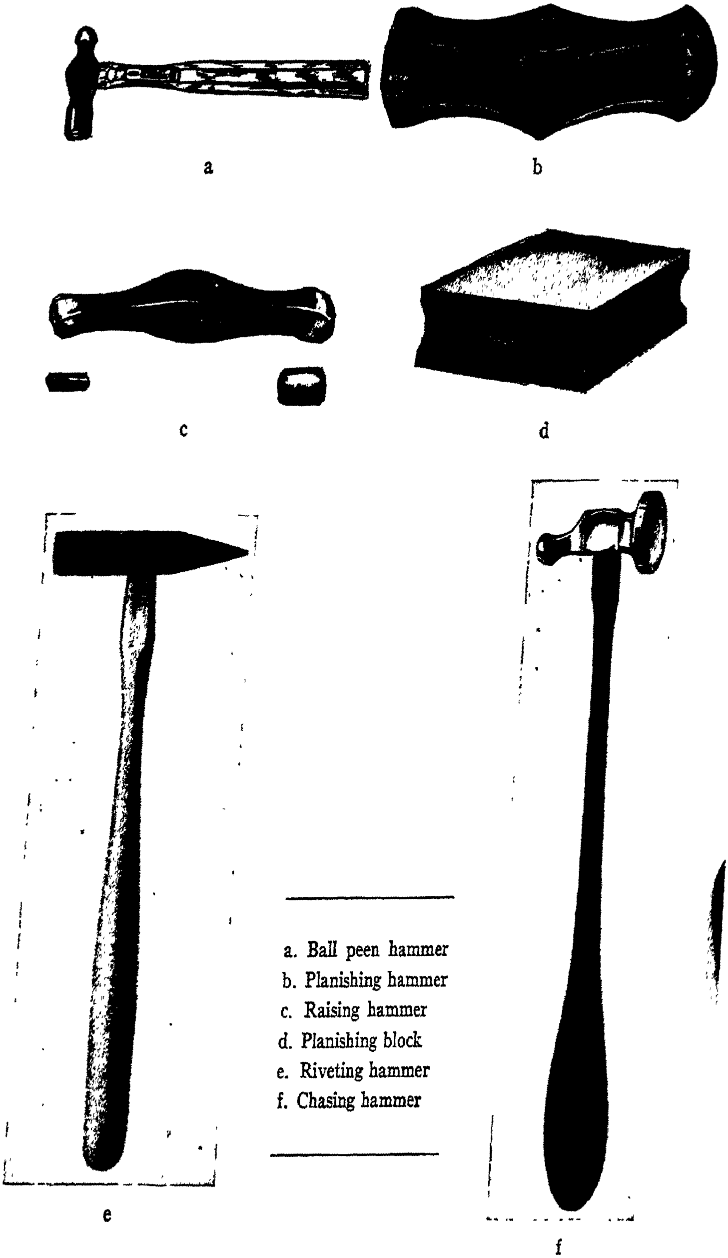


FIG. 2. Hammers for metalcraft.

the stake, since any mark which is present on the hammer or the stake will imprint itself into the metal that is being planished.

A *peening hammer* is much like a planishing hammer except for the fact that the peens or faces are of much smaller spherical radii. These hammers are used much in the same way as the planishing hammer, producing much smaller facets or peen marks on the surface of the metal.

The *chasing hammer* is a special hammer used to tap the chasing tools. These hammers are usually very light. A common pattern is the French type which is illustrated.

Mallets and *soft-face hammers* are used to strike the metal when bending or forming it into shape. *Mallets* are usually made of hard wood in

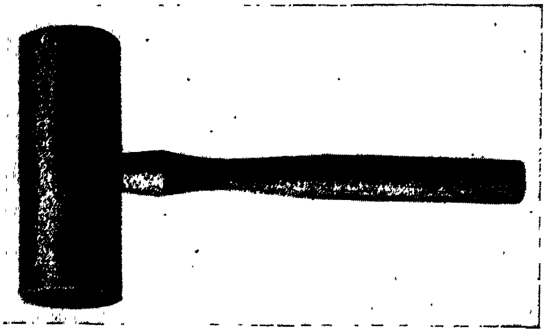


FIG. 3. Mallet.

various sizes and shapes, some especially shaped with a wedge end in order to be used for special work. *Wedge-shaped mallets* are often covered with a piece of leather to keep the wood from splitting and also to provide

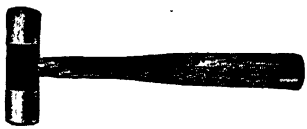


FIG. 4. Soft-faced hammer.

a more even, soft pad at the end of the mallet. Mallet heads are also made of *fiber* or *raw-hide*. These mallets are usually more durable than wooden mallets. A *soft-face hammer* with replaceable plastic tips is quite useful in the craft shop.

A *machinist's vise* is an indispensable item of equipment in the craft shop. The vise is secured to the bench with bolts. The width and the

maximum opening of the jaw determine the size of the vise. An 8″ vise, therefore, will open and clamp a piece of material 8″ wide.

Small bench vises which clamp to the bench are useful when working on small work; however, a vise of this sort will not take the place of a large, sturdy vise. A *pipe vise* is especially useful for holding round bars and pipe while they are being cut and threaded.

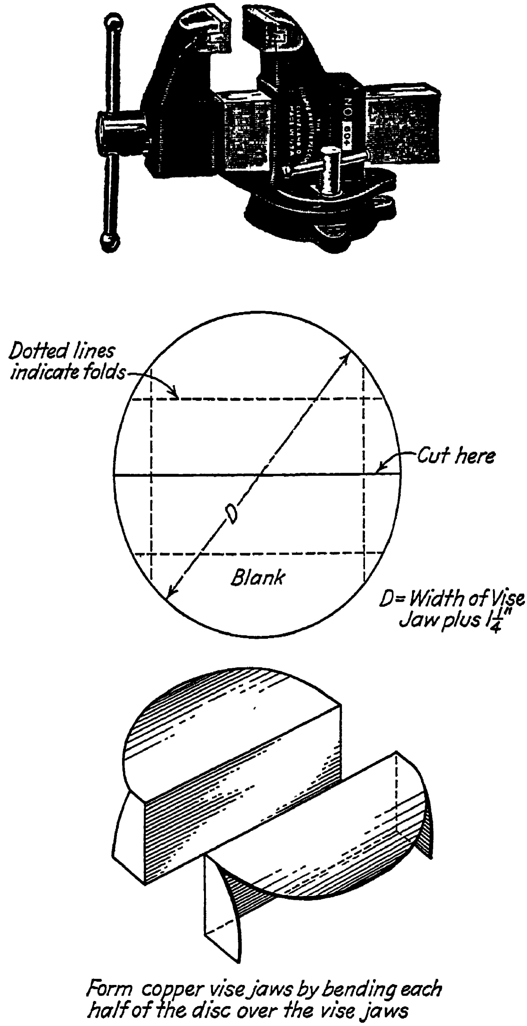


FIG. 5. Machinist's vise and copper vise jaws.

In order to protect the polished work from becoming marked by the rough or toothed vise jaws, it is a good plan to make a pair of soft metal jaws to cover the rough surface of the vise opening. A satisfactory pair of copper jaws can be made by cutting a circular disc of 18 gage copper 1¼″ larger in diameter than the width of the vise jaw. The disc is then cut in two halves on a diameter, and the pieces are placed in the vise and bent over the jaw as shown in Fig. 5.

Clamps are used to hold two or more pieces of material together or to clamp stock to the bench while work is being done. The *"C" clamp* is the most common type used in metalcraft. These clamps may be obtained in sizes from 1″ to 6″ and larger, depending on the size of the work to be clamped. The maximum opening of the clamp determines its size. *Spring*

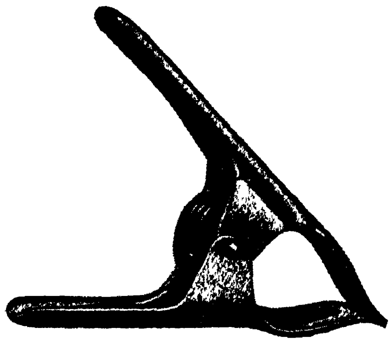


FIG. 6. Spring clamp.

clamps (Fig. 6) are handy to hold pieces when not much pressure is required. These clamps work on the same principle as the spring clothespin. A *bobby pin* or *cotter pin* is often a handy tool for clamping small pieces when soldering them over the flame.

A set of *adjustable end wrenches* (Fig. 7) is an important item in the metal shop in order to make adjustments and repairs on shop equipment. A set including a 6″, 8″, 10″ and 12″ sizes should be sufficient for most purposes.

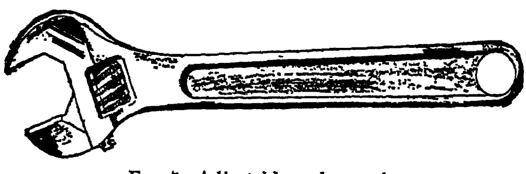


FIG. 7. Adjustable end wrench.

Pliers are used to cut, hold, and form work in the metalcraft shop. There are many sizes and shapes available. One must choose the type most useful for the work to be done. *Side-cutting pliers* can be used for cutting wire as well as for holding work. These pliers are made of tool steel and should not be used over a gas flame as the heat will be no longer effective. They are made in various sizes; a 6″, 7″, or 8″ plier will be best for all-round work. The capacity of these pliers is limited only to the largest size wire which one may cut with them without the help of additional leverage.

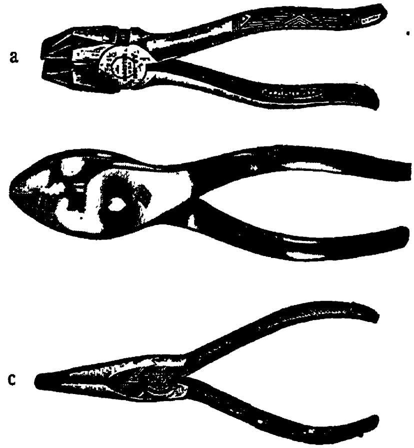


FIG. 8. Pliers.

a. Side-cutting. b. Gas. c. Half-round.

Gas pliers are a cheap type of plier and may be used to hold work over a flame while it is being heated. All other pliers should be kept away from fire since heat will spoil their tempered jaws.

Pliers used for bending and holding small work are classified by the shape of their "nose." Round-nose, flat-nose and half-round pliers are all useful in the metalcraft shop.

A *bending jig* is used in forming band iron when making wrought iron projects. The jig consists of a block of metal with two cylindrical pins set into its surface. One of these pins is usually adjustable for the thickness of the metal being used. The bending jig is held in the jaws of a machinist's vise when being used and the metal is bent in the jig by hand. Never use a hammer on metal being bent in the jig as the jig is not constructed for use with a hammer.

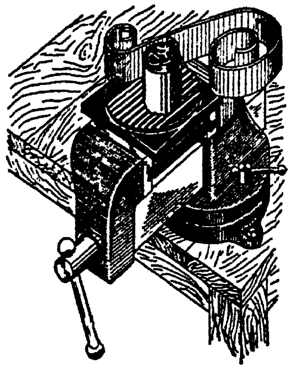
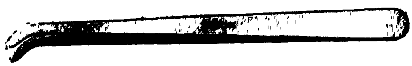


FIG. 9. Bending jig.

Tongs are used to hold work that is being heated and also to fetch work from acid or alkali solutions. Tongs are made of mild steel and in a large assortment of sizes and shapes. Fig. 10 shows two tongs most commonly used in metalcraft work.

a



b

FIG. 10. Tongs.

a. Tongs for removing work from acids b. Bent-nose tongs

Cutting Tools.

Saws for cutting metal are made with a finer tooth than woodworking saws because they are generally used on thinner stock. Metal saws are made also with a replaceable blade which is discarded when dull rather than resharpened.

The ***hack saw*** (Fig. 11) consists of an adjustable frame which is usually fitted with a pistol-grip handle. The blade usually is 8″ or 10″ long and may have 18, 24, or 32 teeth per inch. For most work in cutting thin stock and tubing, the 32-tooth blade is most satisfactory; however, in cutting bar steel of greater thickness, the 24-tooth blade may be used. Blades are made of either carbon tool steel or a special high-speed steel which will not dull as quickly but is more brittle. The tool steel blade is most satisfactory

for the general run of work. Hack saw blades are placed in the saw frame so that the teeth point away from the handle. Blades are generally $\frac{7}{16}''$ wide and .025″ thick.

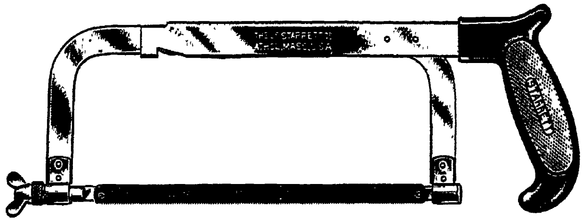
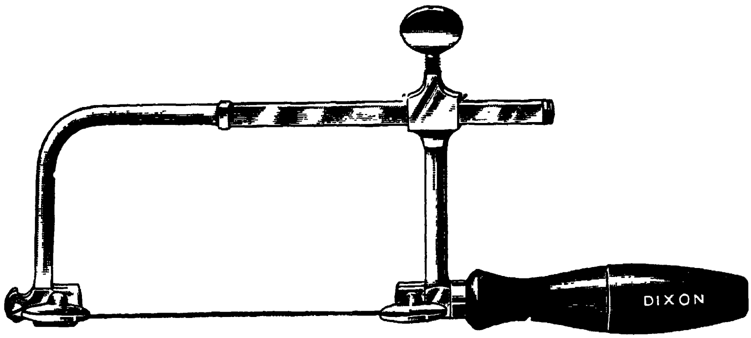
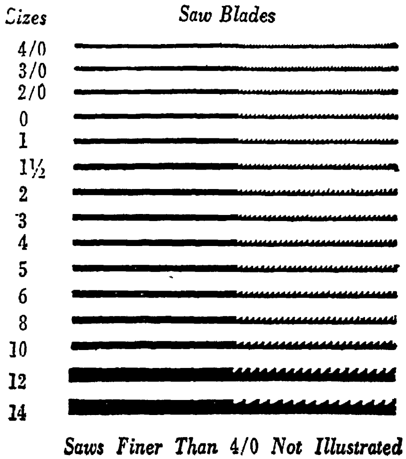


FIG. 11. Hack saw.

The *jeweler's saw* (Fig. 12) has a frame shaped like the letter "C" which is designed to be used with jeweler's saw blades. The frame is ad-



a



b

FIG. 12. Jeweler's saws.

a. Jeweler's saw frame
b. Comparative sizes of jeweler's saw blades.

justable to provide tension for the fine blade which is placed in the frame with the teeth pointing *toward* the handle. The depth of the throat governs the size of the frame. Frames are available in sizes ranging from 2¼″ to 12″. The particular use of the jeweler's saw is to saw or pierce thin metal strips. The smaller sizes are used for small jewelry, while the larger sizes are used on larger sized work. A 4″ saw can be used to saw to the center of a piece of metal 8″ in diameter.

The coarser blades are faster-cutting but do not produce the accurate detail that is possible with a fine blade. For sawing 16 or 18 gage copper, blades ranging from Nos. 2/0 to 5 are satisfactory. Blades are packaged by the gross but are also available by the dozen. Jeweler's saw blades are available in sizes from No. 8/0 to 14 and are 5″ in length.

Files.

Files are made with various cross-sectional shapes and in varying degrees of coarseness. The coarser files are used to remove metal rapidly when shaping a piece of work, whereas the finer files are used to produce a smooth, even surface. The selection of the proper file for the particular work is important. The closer the file fits the contour of the work, the better the result.

The *hand file* is a term generally given to a file which has parallel edges and has faces slightly convex.

The *flat file* is similar in shape; however, the width of the face narrows slightly toward the point.

A *pillar file* is similar to a hand file but narrower.

The *square file* is used for filing square or rectangular holes in metal.

The *half-round file* is flat on one surface and rounded on the other. This file can be used on round or flat work.

The *round*, or *"rattail," file* is used for enlarging round holes in metal or for filing rounded corners.

The *triangular file* is handy to use when finishing off surfaces which meet at less than right angles.

The *crochet file* has both edges rounded and is useful when filing near a rounded corner.

A *warding file* is a very thin flat file which is useful when filing a narrow slot in a piece of work.

A *barrette file* has a flat triangular shape with teeth on one side only. This file is useful in finishing sharp internal corners.

A *knife file* is a file whose cross-sectional shape is like that of a knife This file is also used on work with sharp internal corners.

Half round file.

Triangular or three-cornered file.

Knife edge file.

Round or rat-tail file.

Square file.

FIG. 13. Files used in metalcraft.

The size of a file is indicated by its length, exclusive of the tang. Some of the above shapes are made with "safe" edges which are surfaces with no teeth. This enables one to use the file in the corner of a piece of work without filing the adjacent surface. The file teeth are either single- or double-cut. The single-cut, or *mill files* as they are sometimes called, are used for producing a good finish whereas the double-cut files are generally used for removing excess stock. The coarseness of cut on a file is graded under three classifications: the bastard or coarse cut; the second cut or medium; and the smooth cut or fine. When ordering a file, give (a) the type (cross-sectional shape), (b) the length, (c) the cut, (d) the coarseness of cut. File handles are always sold separately and should be supplied, since a good job cannot be done on work when the file is not handled.

Jeweler's *needle files* (Fig. 14) are small files made in most of the above shapes used for delicate and exacting jobs. These files are available with square or round handles in sizes 4″ to 6″ long and also in assortment sets of six or twelve common shapes.

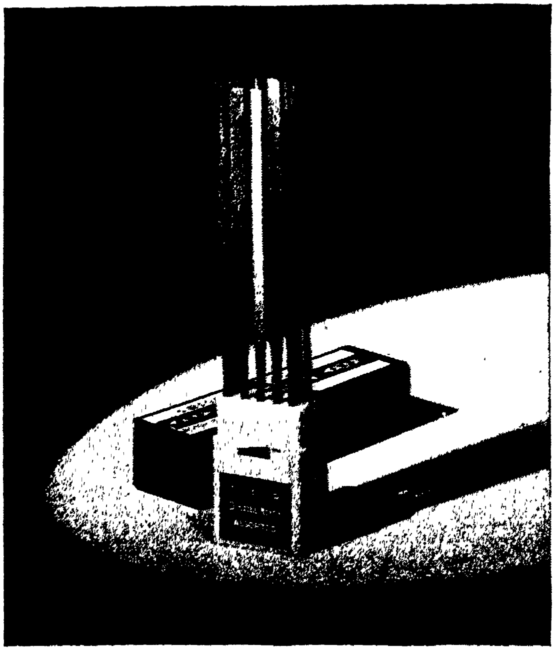


FIG. 14. Jeweler's files.

Chisels.

The *cold chisel* is an impact tool made of tool steel, one end of which is tempered and sharpened for cutting metal. The cutting edge is made in various shapes for special uses. The common shapes are the *straight, cape,* and *diamond point* (Fig. 15).

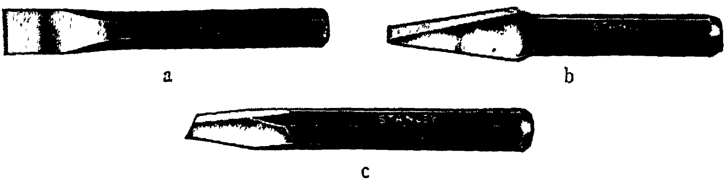


FIG. 15. Chisels.
a. Straight b. Cape c. Diamond point

Shears.

Bench shears are a large shear, one foot or leg of which is held in a bench vise or a slot in the bench. These shears are used on heavy metal (up to 16 gage) and are made 24″ to 39″ in length.

Tinner's shears, or *snips,* are used for small hand work for straight or outside curves (Fig. 16). These shears are most popular in sizes 8″ to 12″.

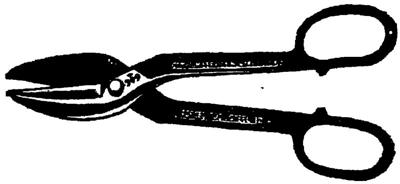
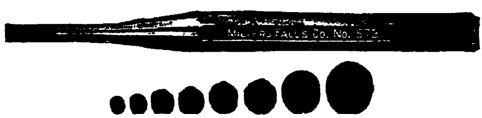


FIG. 16. Tinner's shears.

Aircraft snips are a special compound lever type of snip which cut well with a minimum of power. They are the best general-purpose snip to use around the craft shop for small work. They are available in either "left-" or "right-hand." The most common snip or shear has the lower blade on the left and cuts to the left when held in the right hand. The "right-hand" snip is made with the lower blade on the right and will cut to the right.

Punches.

Solid punches are used to cut or punch holes in sheet metal. The cylindrical end is slightly tapered away from the point so that the hole that is punched is slightly larger than the diameter of the punch near the end. The end of this punch is ground square and flat. Solid punches are available in a number of sizes for various size holes.



a

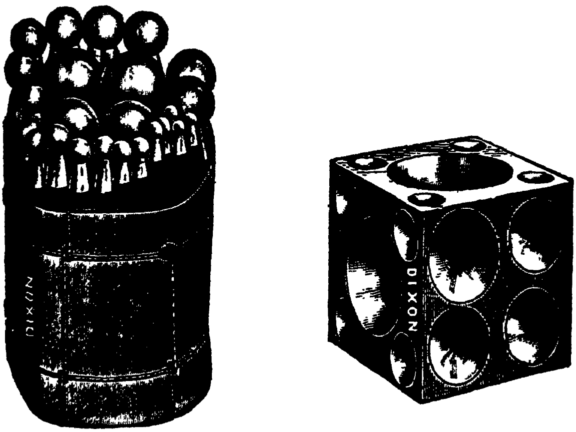
b

FIG. 17. Punches.

a. Solid punch b. Hollow punch

The *hollow punch* is a steel tool with a circular cutting edge used also to punch holes in sheet metal. It will punch larger holes than the solid punch and is available in sizes $\frac{1}{2}''$ to $3''$ diameter.

Dapping punches are used to form small hemispherical shapes in decorating objects made in the craft shop. *Dapping cutters* are used to cut small metal discs that are to be formed with the dapping punch and the *dapping die*. The dapping die is a block of metal with many concave spherical depressions for use with the dapping punch and cutter.



a b

FIG. 18. Dapping tools.

a. Dapping punches b. Dapping block

The *rivet set* (Fig. 19) is a tool used to produce a spherical shape on the end of a rivet after it has been headed over with a hammer. This tool is a bar of tool steel with a concave spherical depression. Various sizes are available for rivets of different diameters.

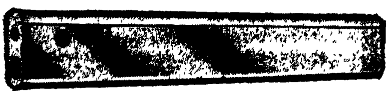


FIG. 19. Rivet set.

Drills.

Drills for metalcraft are available in various sizes. The two most common sets of drills are the fractional set and the numbered size set. A full set of fractional size drills, $\frac{1}{16}''$ to $\frac{1}{2}''$ by $\frac{1}{64}''$, is the most handy set.

This set can be supplemented with a number size set ranging from No. 1 to No. 60. The number size set has a larger selection of in-between sizes which do not appear in the fractional set. Special number size sets of drills may be obtained up to a No. 80 drill which is only .0135″ in diameter. These very small drills are for use in a special drill press which has a very high-speed spindle.

FIG. 20. Twist drill.

NUMBER SIZE TWIST DRILLS AND THEIR EQUIVALENT DIAMETER IN THOUSANDTHS OF AN INCH

No. by Gauge	Decimals of 1 inch	No. by Gauge	Decimals of 1 inch	No. by Gauge	Decimals of 1 inch	No. by Gauge	Decimals of 1 inch
1	.2280	21	.1590	41	.0960	61	.0390
2	.2210	22	.1570	42	.0935	62	.0380
3	.2130	23	.1540	43	.0890	63	.0370
4	.2090	24	.1520	44	.0860	64	.0360
5	.2055	25	.1495	45	.0820	65	.0350
6	.2040	26	.1470	46	.0810	66	.0330
7	.2010	27	.1440	47	.0785	67	.0320
8	.1990	28	.1405	48	.0760	68	.0310
9	.1960	29	.1360	49	.0730	69	.0292
10	.1935	30	.1285	50	.0700	70	.0280
11	.1910	31	.1200	51	.0670	71	.0260
12	.1890	32	.1160	52	.0635	72	.0250
13	.1850	33	.1130	53	.0595	73	.0240
14	.1820	34	.1110	54	.0550	74	.0225
15	.1800	35	.1100	55	.0520	75	.0210
16	.1770	36	.1065	56	.0465	76	.0200
17	.1730	37	.1040	57	.0430	77	.0180
18	.1695	38	.1015	58	.0420	78	.0160
19	.1660	39	.0995	59	.0410	79	.0145
20	.1610	40	.0980	60	.0400	80	.0135

TWIST DRILLS (FRACTIONAL SIZES) AND THEIR DECIMAL EQUIVALENT

Diameter Inches	Whole Length, Inches	Decimal Equivalent	Diameter Inches	Whole Length, Inches	Decimal Equivalent	Diameter Inches	Whole Length, Inches	Decimal Equivalent
1/32	1 7/16	.0312	3/16	3 1/2	.1875	11/32	4 3/4	.3437
3/64	1 11/16	.0468	13/64	3 5/8	.2031	23/64	4 7/8	.3593
1/16	2 1/2	.0625	7/32	3 3/4	.2187	3/8	5	.375
5/64	2 5/8	.0781	15/64	3 7/8	.2343	25/64	5 1/8	.3906
3/32	2 3/4	.0937	1/4	4	.25	13/32	5 1/4	.4062
7/64	2 7/8	.1093	17/64	4 1/8	.2656	27/64	5 3/8	.4218
1/8	3	.125	9/32	4 1/4	.2812	7/16	5 1/2	.4375
9/64	3 1/8	.1406	19/64	4 3/8	.2968	29/64	5 5/8	.4531
5/32	3 1/4	.1562	5/16	4 1/2	.3125	15/32	5 3/4	.4687
11/64	3 3/8	.1718	21/64	4 5/8	.3281	31/64	5 7/8	.4843
						1/2	6	.5

This set can be supplemented with a number size set ranging from No. 1 to No. 60. The number size set has a larger selection of in-between sizes which do not appear in the fractional set. Special number size sets of drills may be obtained up to a No. 80 drill which is only .0135″ in diameter. These very small drills are for use in a special drill press which has a very high-speed spindle.

Fig. 20. Twist drill.

Number Size Twist Drills and Their Equivalent Diameter in Thousandths of an Inch

No. by Gauge	*Decimals of 1 inch*	*No. by Gauge*	*Decimals of 1 inch*	*No. by Gauge*	*Decimals of 1 inch*	*No. by Gauge*	*Decimals of 1 inch*
1	.2280	21	.1590	41	.0960	61	.0390
2	.2210	22	.1570	42	.0935	62	.0380
3	.2130	23	.1540	43	.0890	63	.0370
4	.2090	24	.1520	44	.0860	64	.0360
5	.2055	25	.1495	45	.0820	65	.0350
6	.2040	26	.1470	46	.0810	66	.0330
7	.2010	27	.1440	47	.0785	67	.0320
8	.1990	28	.1405	48	.0760	68	.0310
9	.1960	29	.1360	49	.0730	69	.0292
10	.1935	30	.1285	50	.0700	70	.0280
11	.1910	31	.1200	51	.0670	71	.0260
12	.1890	32	.1160	52	.0635	72	.0250
13	.1850	33	.1130	53	.0595	73	.0240
14	.1820	34	.1110	54	.0550	74	.0225
15	.1800	35	.1100	55	.0520	75	.0210
16	.1770	36	.1065	56	.0465	76	.0200
17	.1730	37	.1040	57	.0430	77	.0180
18	.1695	38	.1015	58	.0420	78	.0160
19	.1660	39	.0995	59	.0410	79	.0145
20	.1610	40	.0980	60	.0400	80	.0135

Twist Drills (Fractional Sizes) and Their Decimal Equivalent

Diameter Inches	*Whole Length, Inches*	*Decimal Equivalent*	*Diameter Inches*	*Whole Length, Inches*	*Decimal Equivalent*	*Diameter Inches*	*Whole Length, Inches*	*Decimal Equivalent*
$\frac{1}{32}$	$1\frac{7}{16}$	.0312	$\frac{3}{16}$	$3\frac{1}{2}$	.1875	$\frac{11}{32}$	$4\frac{3}{4}$	.3437
$\frac{3}{64}$	$1\frac{11}{16}$	.0468	$\frac{13}{64}$	$3\frac{5}{8}$	.2031	$\frac{23}{64}$	$4\frac{7}{8}$	.3593
$\frac{1}{16}$	$2\frac{1}{2}$	.0625	$\frac{7}{32}$	$3\frac{3}{4}$	.2187	$\frac{3}{8}$	5	.375
$\frac{5}{64}$	$2\frac{5}{8}$	.0781	$\frac{15}{64}$	$3\frac{7}{8}$	.2343	$\frac{25}{64}$	$5\frac{1}{8}$	.3906
$\frac{3}{32}$	$2\frac{3}{4}$	.0937	$\frac{1}{4}$	4	.25	$\frac{13}{32}$	$5\frac{1}{4}$	.4062
$\frac{7}{64}$	$2\frac{7}{8}$	.1093	$\frac{17}{64}$	$4\frac{1}{8}$	.2656	$\frac{27}{64}$	$5\frac{3}{8}$	.4218
$\frac{1}{8}$	3	.125	$\frac{9}{32}$	$4\frac{1}{4}$	.2812	$\frac{7}{16}$	$5\frac{1}{2}$	.4375
$\frac{9}{64}$	$3\frac{1}{8}$	.1406	$\frac{19}{64}$	$4\frac{3}{8}$	.2968	$\frac{29}{64}$	$5\frac{5}{8}$	.4531
$\frac{5}{32}$	$3\frac{1}{4}$	.1562	$\frac{5}{16}$	$4\frac{1}{2}$	.3125	$\frac{15}{32}$	$5\frac{3}{4}$	.4687
$\frac{11}{64}$	$3\frac{3}{8}$	.1718	$\frac{21}{64}$	$4\frac{5}{8}$	.3281	$\frac{31}{64}$	$5\frac{7}{8}$	.4843
						$\frac{1}{2}$	6	.5

When drilling work in places where no electric current is provided, a *hand drill* (Fig. 21) is used with the above drill points. Most hand drills have a capacity of 0″ to ¼″. Some hand or *breast drills* have larger capacities.

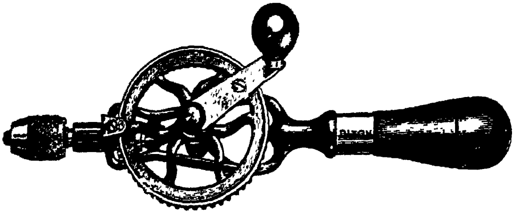


FIG. 21. Hand drill.

Countersinks (Fig. 22) are used to make a conical depression in the surface of the metal through which a hole has already been drilled. These are used especially on holes that are to receive a flat-head screw. The correct countersink for this purpose is one with an 82-degree included angle which is the angle of the flat-head screw.

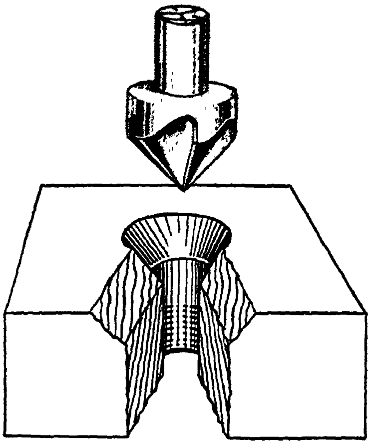


FIG. 22. Use of a countersink.

Taps and Dies.

A *tap* is a piece of round tool steel with a thread on one end and a square shank on the other. The threaded portion is fluted with grooves cut across the threads and parallel to the axis. These grooves form cutting edges on

the threaded part and allow a space for removal of chips. Taps are available in three forms: the taper or starting tap, the plug tap and the bottoming tap. A *tap wrench* is a handle used to hold the tap while turning the tap into the tap hole.

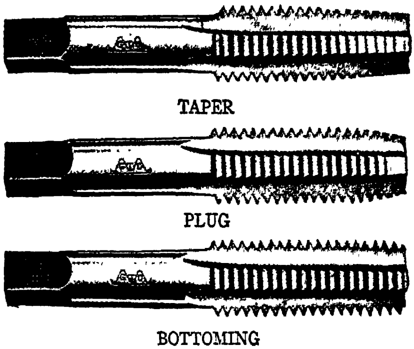


Fig. 23. Common taps.

A *die* is a tool for cutting external threads on a cylindrical piece of stock. The most common type of die is the round split die which can be adjusted for either a tight- or loose-fitting thread. The tool used to hold the die while turning it on work to be threaded is called a *die stock.*

Fig. 24. Die and die stock.

Thread sizes for taps and dies are divided into two general classifications. Sizes under $\frac{1}{4}''$ outside diameter are generally available in machine screw sizes which is a numbered size system designating the outside diameter of the bolt. To determine the decimal equivalent of a machine screw, multiply the size by 13 and add 60; thus you may convert a No. 5 machine screw to .125″ or $\frac{1}{8}''$ diameter. Sizes over $\frac{1}{4}''$ are usually available in fractional sizes.

Threads are classified also as to their pitch or number of threads per

inch. There are two standard series of sizes used in metal work, the *National Fine* and the *National Coarse* series. The following table gives the various sizes in each series of threads and also the "tap hole" size or drill size to be used before tapping a thread:

TAP DRILL SIZES FOR COMMON SCREWS IN THE METALCRAFT SHOP

National Coarse Series		National Fine Series	
Nominal Size	Tap Drill Size	Nominal Size	Tap Drill Size
4 – 40	43	4 – 48	42
5 – 40	38	5 – 44	37
6 – 32	36	6 – 40	33
8 – 32	29	8 – 36	29
10 – 24	25	10 – 32	21
12 – 24	16	12 – 28	14
1/4 – 20	7	1/4 – 28	3
5/16 – 18	1/4	5/16 – 24	17/64
3/8 – 16	5/16	3/8 – 24	11/32
7/16 – 14	3/8	7/16 – 20	25/64
1/2 – 13	27/64	1/2 – 20	29/64

Stakes (Fig. 24a) are used in metalcraft work for various bending, forming, raising, and planishing operations. The stake has a square tang which may be held in a bench vise or a metal bench plate which is recessed into the stake bench for the purpose of holding stakes.

A common set of sheet metal stakes is a good set for bending metals into various shapes. Various others are available to conform with the contour of the work. Stakes should be kept free from dirt and with a mirror-like surface so that the metal being worked on them will not become marred by some imperfection in the surface of the stake.

The *anvil* is made of cast steel with an upper surface or face of hardened steel welded onto it. It has a conical horn with a flat section, which is soft, and its other end is rectangular with a round and a square hole through it. The hardened face is used for forging and general hammering, and the soft flat on the horn for cutting off either hot or cold stock with a chisel. The holes are used for bending purposes and for holding special tools. A good anvil, suitably mounted, is a very great help to the metalworker.

The standard *twist drill gage* is helpful in checking the size of a numbered twist drill. A table on the gage provides the user with the proper tap drill size for various machine screw taps.

The *American Standard wire gage* (Fig. 26) is used to gage the thickness of sheets, plates, and wire of nonferrous metals such as copper, brass, and aluminum. The B & S gage size is stamped on one side of the gage while the reverse side is marked with the decimal equivalent.

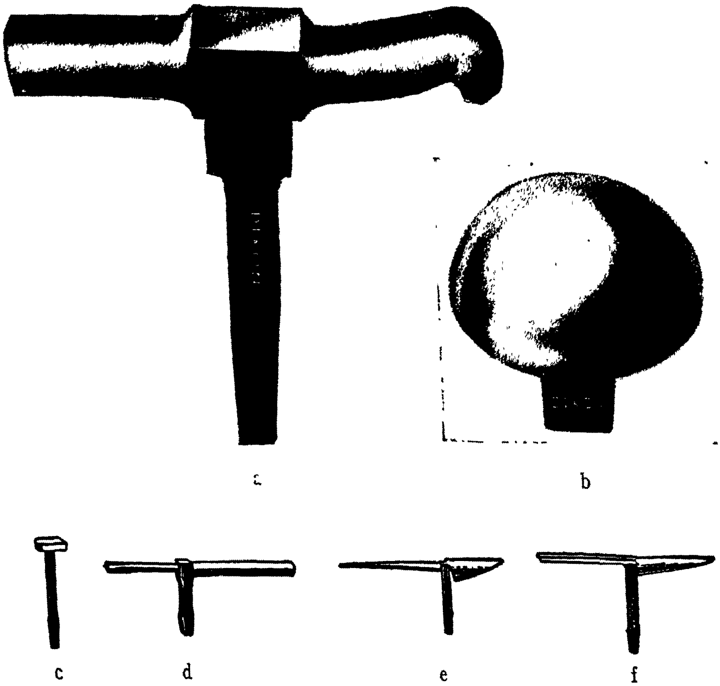


FIG. 24a. Stakes used in metalcraft.

a. "T" stake
b. Planishing stake
c. Coppersmith's stake
d. Conductor stake
e. Blowhorn stake
f. Beakhorn stake

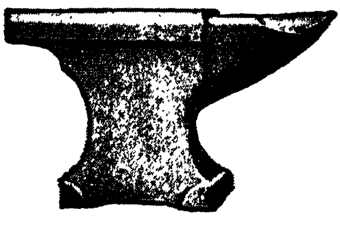


FIG. 25. Anvil.

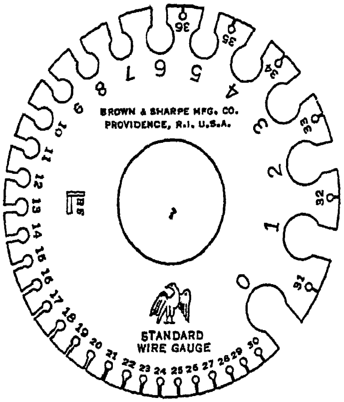
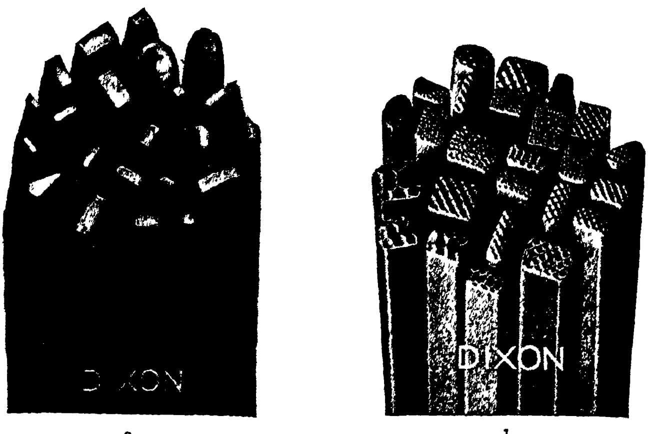


FIG. 26. American Standard wire-gage.
Courtesy Brown & Sharpe Mfg. Co.

Chasing tools are used in raising a design on copper or brass. The end of the tool is hardened and tempered and highly polished. There are many varied shapes and sizes for lining, raising, sinking, flattening, and planishing. Chasing tools are sold in sets of twelve, twenty-five or fifty. Handy sets can be made up to the individual's design in the craft shop from tool steel bars.

Matting tools are used to give a decorative treatment to the background in order to give contrast to the raised design. These tools are also made of



a b

FIG. 27. Chasing and matting tools.
a. Chasing tools b. Matting tools

tool steel and the ends are of various shapes in order that one may fit the tool into the contour of the work. The surface of the end of the tool is serrated to produce a stippled effect on the work. These tools also are available in sets of twelve, twenty-five or fifty.

Heating Equipment.

If gas is available in the metalcraft shop, a two- or three-burner gas furnace is handy for annealing metal projects and heating soldering irons. Provision should be made in the gas line for one or more *Bunsen burners* which are almost an essential when soldering pieces of metal. For heating large areas which are difficult to heat in the gas furnace, a *blow pipe* equipped with a regulating valve for gas and air is used. The air may be delivered to the torch by a *foot power blower* or, when used more often, the rotary power blower gives more efficient service.

There is an *alcohol blow torch* on the market for use in soldering in localities where no gas is available. This torch furnishes its own pressure and does not require a mouth blow pipe.

Tools Necessary for Doing Repoussé Work on Thin Sheet Metal.

For tooling a design on thin metals, the following tools are found most useful: a leather modeling tool for pressing the metal from the rear in order to raise the design and a *felt pad* to provide a backing for the metal as it is being modeled. The simplicity of the equipment used for this work makes it adaptable to almost any craft room without the necessity of obtaining expensive equipment.

Sheet Metal Machines.

There are a number of sheet metal machines which will be helpful in a metalcraft shop. These machines are not absolutely necessary in order to perform the work of a craftsman; however, they will be an asset to the shop if they are made available.

The *squaring shear* is a foot-powered machine used to cut straight and square edges on flat metal sheets. The capacity of the machine is limited to the length of the knife and the maximum thickness of the metal which it will safely cut. The maximum gage is usually marked on the machine near the knife.

The *slip form roller* is used to roll a flat sheet of metal into a cylindrical shape. The top roll may be raised for the removal of work after it is formed.

The *bar folder* is used to *hem* an edge on flat sheets of metal or for bending metal edges in preparation for wiring and seaming.

The *disc cutter* is a machine used to cut a circular disc from a square blank of metal. The machine has an adjustment for discs ranging from 2″ to the capacity of the machine. This machine is very handy in preparing circular discs for use in raising, forming, and spinning.

Power-Driven Machine Tools.

Grinder. The offhand grinder is a very important power tool for the metal shop. It may be obtained in the pedestal or the bench type with a wide variety of wheel sizes. Accessories are often available so that the grinder can be used for several other operations, such as buffing and sanding.

For the metalcraft shop, a bench grinder using 6″ to 8″ wheels is a practical size. In ordering a grinder, it is necessary to specify the type of grinding wheel, or to ask the manufacturer to supply a wheel that will be suitable for the job to be done.

The *drill press* is an important machine tool in the craft shop. This machine can be obtained in either a bench or floor model. The drill or bit is held in a *drill chuck* which should have a capacity of 0-½″.

Motorized Hand Tools.

These tools are very useful for small jobs of grinding, polishing, drilling, carving, and engraving. A motor is directly connected to a chuck, which holds a large variety of small rotary tools. The motor and tools are usually contained in a convenient carrying case.

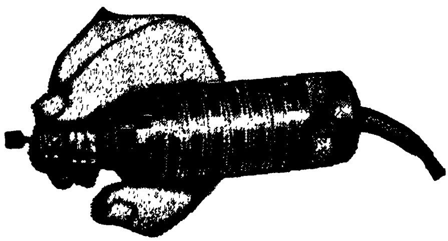


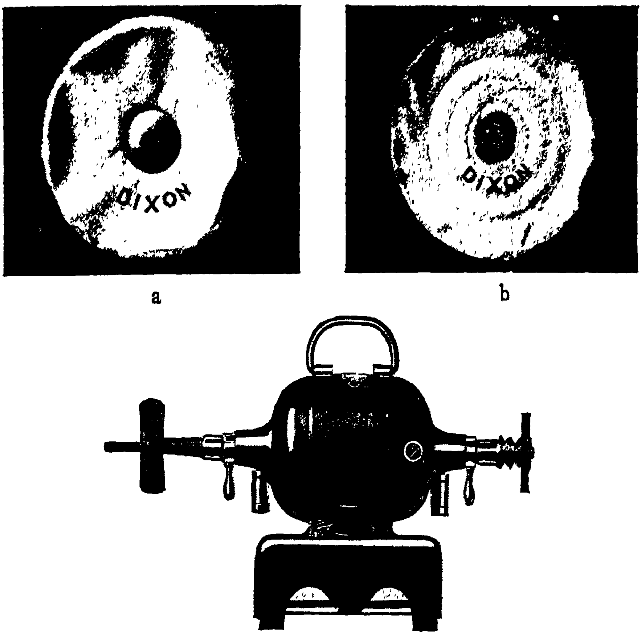
FIG. 28. Motorized hand tool.

Probably the most important piece of power machine equipment in the craft shop is the *buffing machine*. This machine has a revolving spindle driven either directly by a motor or by being belted from a motor. The

spindle has two tapered ends which are threaded to take the various buffing wheels for polishing. The best buffing machines are provided with a splash guard which is used to protect the operator from becoming spattered with buffing compounds or objects which may be thrown off the wheel when buffs are revolving at a high speed. The speed of a buffing spindle should be 1800 to 2000 rpm.

Buffing wheels for the buffing machine are made of several different materials in a variety of shapes. The most common wheels are: the *muslin buff,* both sewed and unsewed with a lead center; the *cotton flannel buff;* and the *felt buff.* All these buffs are used for the general purpose of "cutting" down the roughness of the surface and producing the final luster that finishes the work. These wheels are available in different diameters and shapes in order to obtain a finish on various shaped pieces.

Brass and steel *wire scratch brushes* produce a satin or brushed finish. *Bristle* brushes are used to polish special shapes which are not readily polished with the solid or buffing wheels. With the bristle brush, one may also



a b

c

FIG. 29. Buffing equipment.
a. Loose cotton buff b. Heavy muslin c. Buffing lathe

obtain a satin finish. These brushes come in a number of shapes to fit surfaces which are hard to reach.

A patented *rubber-abrasive composition wheel* is excellent for grinding away deep scratches on work. These wheels can also be used to remove ugly rust stains from tools.

Foundry Equipment.

A *foundry* is a place where a sand mold can be made into which metal may be poured in order to form a metal casing. Molds are generally made in molding sand which is available in various coarsenesses depend-

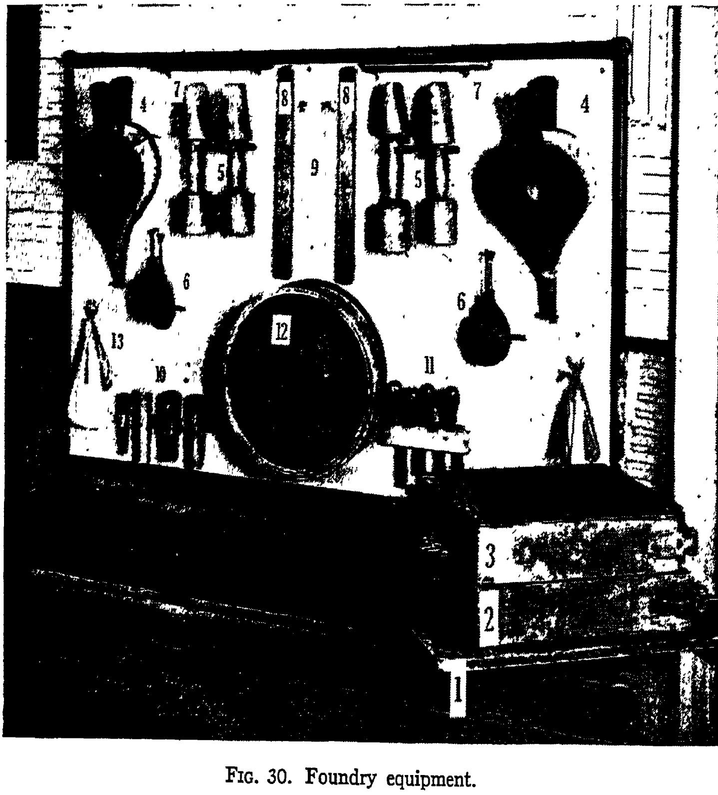


FIG. 30. Foundry equipment.

1. Molding board
2. Drag
3. Cope
4. Molder's bellows
5. Ram
6. Bulb sponge
7. Sprue cutter
8. "Striking-off" iron
9. Vent wires
10. Sprue pins
11. Slicks
12. Riddle
13. Parting sand

ing on the type of casting work being done. The molding sand is mixed with water in order to hold its shape and may be reused in molding indefinitely. *Parting sand* (a talc powder) is used to dust over the pattern and between the two parts of the mold to keep the damp sand from sticking. Fig. 30 shows the various tools used in making a mold.

Metal Spinning.

Metal spinning is done either on a metal lathe, a woodworking lathe, or a lathe designed especially for spinning. The speed should be about

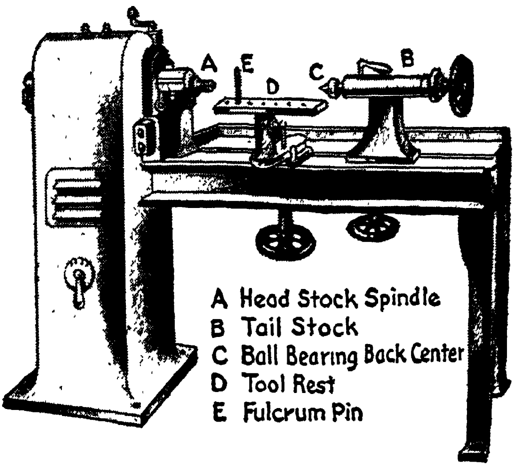


FIG. 31. Metal-spinning lathe.

800 rpm to 1200 rpm. Several essential tools which are not supplied with the lathe are discussed below:

The Chuck. It is necessary to buy or make a chuck of metal or hard wood, whose outside contour is shaped to the exact inside contour of the spun article. The chuck must be provided with a threaded portion to screw onto the lathe spindle or it can be fastened to a faceplate. It is important to have this chuck run true so that the spun article will be perfectly symmetrical. In fact, it is impossible to spin unless the chuck does run true. If the craftsman turns the hard wood chucks himself, he can make his own designs, thus adding much interest and personal satisfaction to the work.

When spinning a deep dish or vase, it is often necessary to make a series of chucks, each one of the series being progressively nearer to the desired shape of the spun article. It is possible to spin articles which have a neck

smaller than the bottom by the use of a chuck made in sections which will come apart when it is necessary to remove it from the spun metal.

The Back Center. The metal disk from which the article is spun is held to the chuck by means of a special support or spinning center held in the tailstock. This support consists of two parts—a "follow block" which is a piece of hard wood about ½″ thick, turned down to a diameter a little smaller than the bottom of the article being spun, and a bearing, preferably a ball-bearing assembly, to allow the block to rotate with the metal while it is being held against the chuck (Fig. 32).

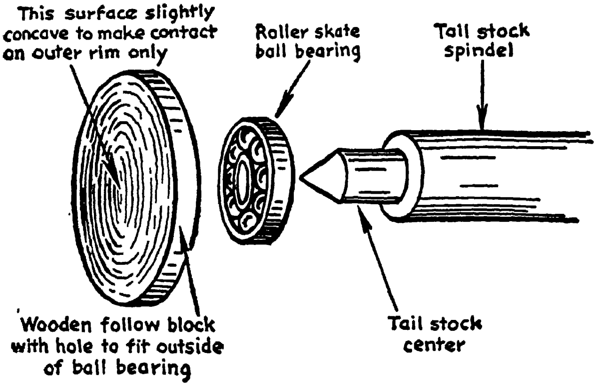


FIG. 32. The back center.

The follow block may be held on the point of the dead center or on a special dead center which has a pin in place of the 60-degree center. In this case, a hole to fit the pin is made in the follow block with a Forstner bit. A convenient and efficient ball-bearing center may be made by holding a roller skate bearing on the dead center, the outside of which fits a hole in the follow block. The follow block is usually slightly concave on the side which is against the metal. A little rosin will help to keep the disc from slipping.

The Tool Rest. The support for the spinning tool consists of a flat horizontal bar of iron supported in the rest holder of the lathe at a height slightly below the center of the disc. Holes are bored in this bar at intervals of about 1″ for the purpose of inserting a steel pin, which acts as a fulcrum for the spinning tool. The fulcrum pin should be shouldered, in order to prevent it from falling through the hole in the bar. It is con-

venient to have two of these pins because, in the process of spinning, it is sometimes necessary to use two spinning tools at the same time.

Spinning Tools. For the beginner, a hard wood dowel stick or a broom handle, pointed as shown in Fig. 33A, and a *back* stick (B), with a flat beveled end, are sufficient for the soft metals. These sticks should be about 2½″ long and about 1″ in diameter. A file sharpened as shown (C) makes a handy trimming tool. There are available sets of metal-spinning tools which, in the hands of an experienced spinner, will do the work quickly and efficiently; however, wooden tools must be kept in good condition, that is, smooth with no sharp edges to cut or mar the surface of the metal.

Fig. 33. Spinning tools.

Chapter III

OPERATIONS AND PROCESSES IN METALCRAFT

Making A Layout.

The first step, after one has decided on the project to be made in the metalcraft shop, is to make a layout on the metal to be used. It is a good plan, in most instances, to cut a piece of material to rough measurements allowing some material for waste and then make the layout. The following layout procedures for various shapes are described.

Square or Rectangular Blank.

Procedure:

1. Cut a piece slightly larger than the dimensions required.
2. Select one straight edge on the blank as the edge to be used for measuring and squaring.
3. Holding the machinist's square on this edge, scribe a line at right angles to this edge as near the end of the stock as possible.
4. The width of the rectangle is measured from the first edge and marked at two points. The marks are then connected with a scriber and straightedge. Narrow pieces may be easily marked, setting the machinist's square at the required width and marking as illustrated in Fig. 34.
5. The length of the rectangle is measured from the line scribed in step 3 and a line is marked at this point holding the head of the square on the original straight edge.

The accuracy of the rectangular piece depends a great deal upon the care taken in making the layout. Be sure to measure and mark carefully. Hold the scriber slanting in the direction the line is being drawn and also slanting toward the blade of the square or straightedge.

Circular disc. It is usually important to prepare a circular disc which will not be marred by the divider or punch in the center. For this reason, it is a good plan for the craftsman to prepare a centering piece on which he may place the divider point when marking the circumference. This

piece may be made by cutting a piece of copper 1″ x 1″. The diagonals are then drawn on this square and a center punch mark is made at their intersection.

FIG. 34. Marking the width of a narrow piece using a machinist's square and scriber.

Procedure:

1. Prepare a square blank about ¼″ larger than the diameter of the desired circle.
2. With a lead pencil and straightedge, draw the diagonals of the square.
3. Place the centering piece described above on the blank so that its corners line up with the diagonals of the blank.
4. Open the dividers to the radius required and, with one leg of the dividers on the punch mark in the centering device, scribe the circle.

Fig. 35. Laying out a circular disc with dividers. (Notice the use of centering piece to eliminate center mark on work.)

Lean the dividers in the direction of rotation so that the point is pulled along its path as shown in Fig. 35. Hold the centering device securely with the left hand or fasten it to the disc blank with tape.

Laying Out an Irregular Contour Using a Template. An irregular contour may be layed out on a piece of metal by using a pattern or template. The following method will be found to be successful when but one object is to be marked out on the metal and is indispensable when laying out a series of duplicate parts. The template may be made of a stiff paper such as an *oak tag* or, for more permanence, from sheet metal.

Procedure:

1. Select the contour to be used or make a sketch of the shape on a piece of paper.
2. If the sketch is to be used full size, transfer it on a piece of *oak tag* and cut it out with scissors.
3. If it is necessary to enlarge or reduce a design, draw a series of squares over the design and also on the template material to the proper scale and draw the contour by using the squares. Cut out the template with scissors.
4. Clean the surface of the metal and mark the outline of the template on the metal, using a scriber or sharp pencil.

Cutting Metal.

Hack Saw. Bars of iron, tubes, and heavy sheets of metal are best cut by using the hack saw. The proper blade is dependent on the cross-sectional area of the piece being cut. A blade is selected which will permit at

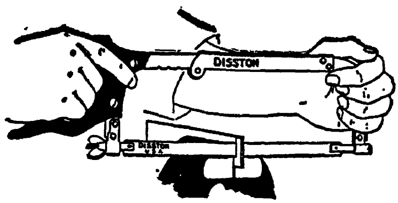


Fig. 36. Correct method of holding hack saw frame.

least three teeth to cut at the smallest section of the piece being sawed. A 32-tooth blade is best for sheets, tubing, and shapes with a small cross-sectional area. Larger bars will cut faster by using a 24- or 18-tooth blade. When the proper blade has been selected, place it in the hack saw frame with the teeth pointing away from the handle and adjust the tension of the blade fairly taut in order to prevent buckling. Place the work in a vise or secure it by clamping it to the bench. When held in the vise, best results will be obtained if the work is arranged so that the cut is close to the vise jaws.

Procedure:

1. Hold the saw with the handle in the right hand and the front end of the frame in the left.

2. Place the front end of the blade on the mark and start the cut with a forward stroke.
3. Release the pressure on the return stroke and repeat the process gradually increasing the pressure on succeeding forward strokes.

Using Tinner's Shears or Aircraft Snips. Straight cuts are made usually with the straight tinner's shears. Aircraft snips may be used to good advantage on heavy metal or for making straight or curved cuts.

Procedure:

1. Grasp the snips in the right hand and the metal in the left.
2. Open the blades and insert the sheet as far as possible into the jaws.
3. Place the cutting edge of the upper blade exactly on the line of the cut, and proceed as with ordinary scissors.
4. When approaching an inside corner, do not allow the end of the blades to extend beyond the corner line.

Circular discs are cut from square blanks. The straight shear or aircraft snips may be used. Cut on the line, holding the work in the left hand and removing the waste material in one piece. Inside and irregular curves are cut best by using the aircraft snips. A large hole may be cut in a metal sheet by first punching a hole in the waste stock with a hollow punch and then inserting the blade of the aircraft snips from the under side of the metal and cutting to the outline.

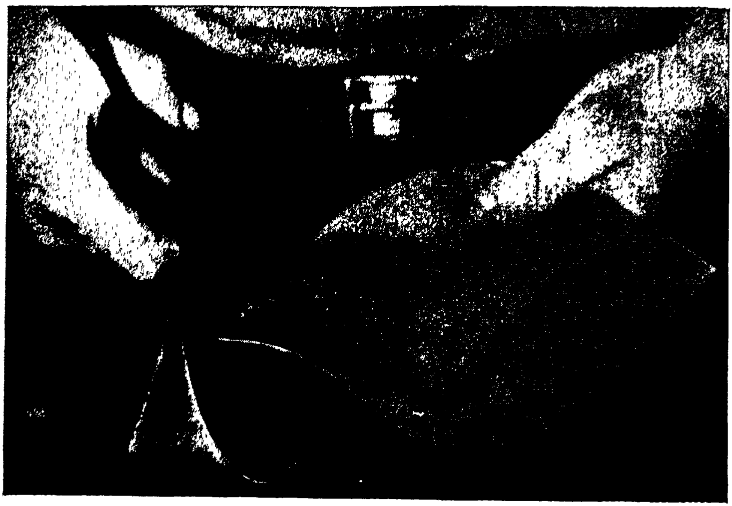


FIG. 37. Cutting a circular disc using straight tinner's shears.

Using a Cold Chisel. Grasp the chisel in the left hand and the hammer in the right. Do not grip them too tightly. The hammer should be held back toward the end of the handle to allow a free easy swing. Hit the head of the chisel a solid blow. The cutting edge should be kept on the line of cut. If the chisel is held too high, it will "dig" or cut too deep; if it is held too low, it will drift away from the line. Watch the cutting edge as you strike the blow. In this manner the cut can be directed accurately.

Place a supporting block beneath the work in the vise. This prevents the work from slipping downward in the vise jaws and keeps the line of cut parallel to the top surface of the vise.

Do not allow the head of the chisel to become mushroomed or spalled from excessive hammer blows. Grind it off occasionally. It is always wise to wear goggles when chiseling.

Lubricate the chisel occasionally with oil or soap when chipping wrought iron, brass or copper. When working on cast metals, it is good form to cut from each edge to the center, as corners are liable to break off below the finish line. For the same reason, ease up on the hammer blows as one cut approaches the other.

Using a Jeweler's Saw. A jeweler's saw is used to cut irregular curves in sheet metals and especially for piercing intricate designs in projects made of the various art metals. The work is held over a wooden bench pin or block of wood having a V cut on its surface. The best blade for most work will range from No. 2/0 to No. 2.

Procedure:

1. Place the wooden bench pin in a vise, or clamp it to the bench top with a "C" clamp so that the V extends over the edge of the bench.
2. Prepare a paper pattern of the design to be used and cement the paper to the metal using rubber or paper cement.
3. If the work is to be pierced, a hole must be drilled in the waste stock for the purpose of inserting the saw blade.
4. Insert the blade in the saw frame so that the teeth point toward the handle. Adjust the frame so that the blade is taut.
5. Assume a position at such a height that the forearm, when held horizontal, is in the plane of the bench pin.
6. The cut is started on a downward stroke, slanting the saw slightly toward the direction of the desired cut.
7. After the cut has been started, the saw is held vertically and may be lubricated by rubbing a bit of beeswax on the blade.

Especial care must be taken, when working around a small radius, to keep the saw in motion and to hold it so that the blade is vertical. Any pinching of the saw blade in its kerf may break the blade.

FIG. 38. Sawing with a jeweler's saw.

Cutting Stock with the Squaring Shear. The squaring shear may be used to cut straight, square edges on sheet stock. There is a limit to the gage and width of metal that can be cut with the squaring shear. When the shear is new, there is a plate fastened to the machine giving this information. Before cutting, a layout should be made in pencil on the stock in such a way as to insure the best use of the stock with the least waste.

Procedure:

1. Place the longest straight edge of the stock to be cut against the guide fence of the machine and by stepping on the treadle, trim about $\frac{1}{16}''$ off the end in order to insure a square end.
2. Make a measurement of width required and cut off stock.

3. Holding the longest edge of the piece of stock against the guide fence, cut the stock to length. *Caution*: Take care not to have fingers near the cutting knife. Be sure no one is standing near the machine with his foot under the treadle.

Cutting a Disc on the Circular Shear.

Procedure:

1. Prepare a square blank at least $\frac{3}{16}''$ larger in diameter than the size of the disc required.
2. Set the machine, by the gage, for the correct diameter required.
3. Start the cut near the corner of the square, cutting about $\frac{1}{16}''$ in from the edge and guide the blank until it is centered under the clamping pads.
4. Clamp the blank in position and cut the disc.
5. If the disc is required to be cut to exacting measurements, set the machine and cut a disc of black iron to determine the size and adjust the machine if necessary.

Filing.

Filing a Flat Surface (cross filing). The size of the file that is to be used for a job depends on the surface which is to be filed. A fairly large flat surface requires a 10″ or 12″ file whereas a smaller surface is usually filed with a 6″ or 8″ file. If a good amount of material is to be removed, select a 10″ flat file with a bastard cut. In order to file properly, a handle should be secured to the tang of the file.

Procedure:

1. Secure the work in the vise so that the surface to be filed is held horizontal.
2. Grasp the handle of the file in the right hand and the toe of the file in the left.
3. Hold the file obliquely to the work and file by pushing the file across the work and, at the same time, along the work.
4. Release the pressure on the return stroke and repeat the procedure, taking care not to rock the file over the surface.
5. From time to time, clean the metal particles from the file by using a *file card.*

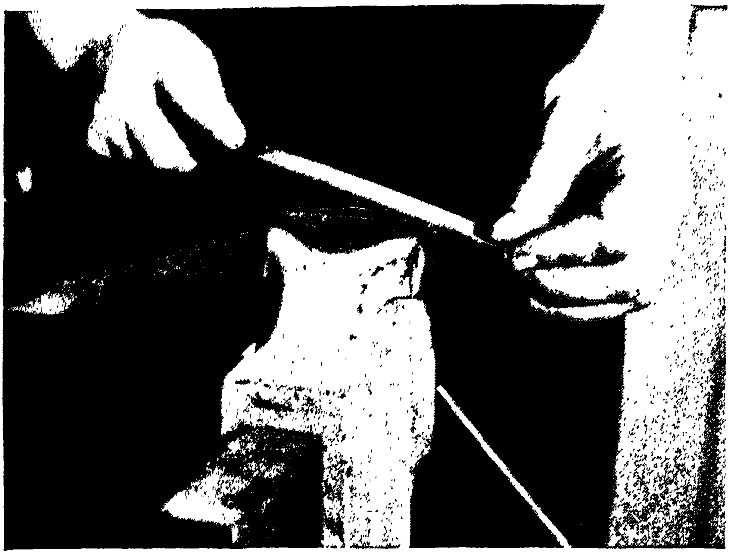


FIG. 39. Cross-filing a piece of metal held in a vise.

Draw Filing. In order to obtain a better finish before polishing, it is a good plan to draw-file the surface. This operation is done with a mill file of about the same length as is used in the above procedure. The file is held in both hands, as illustrated in Fig. 40, and drawn over the work to "true up" the surface and remove any marks left in the work from cross filing.

Miscellaneous Filing Work. The thin edge of a plate or disc of metal can be filed by holding it over the edge of the bench and by filing the edge with a mill file in the direction of the metal. A 6″ or 8″ half-round, second-cut file is handy for filing into the corner of an edge design, holding the metal against a hard wood block held in the vise. Small, intricate work may be filed with jeweler's needle files, selecting the file that most nearly fits the contour of the work. Tool steel should be annealed before filing since the hard surface may destroy the cutting edge of the file.

Care of Files. Files should be stored in a rack which is so designed as to permit them to be removed and replaced without touching any metal surface. Care must be taken, especially with small files of thin cross section, to prevent breakage from applying too much pressure. A file, as well as being hard, is brittle and will not bend to any extent without breaking.

Fig. 40. Draw-filing.

Drilling.

A hole is drilled in metal with a twist drill. This drill or bit is held in the chuck of a *hand drill* or *drill press,* depending on whether the hole is to be drilled by power or by hand. Before the hole is drilled in metal, its center must be located on the metal and the hole is then marked with a center punch. The mark made by the center punch will aid in starting the drill in the correct location.

Procedure used in drilling a hole with a hand drill:

1. Locate the center of the hole to be drilled.
2. Center-punch this point using a hammer and center punch.
3. Select the proper size drill for the job and place it in the hand drill.
4. Secure the work to the bench in a way that will prevent a hole from being drilled in the bench.
5. With the left hand on the handle and the right hand on the crank, place the drill point on the punch mark and adjust the position of the hand drill so that the drill is at right angles to the surface being drilled.

6. With the right hand, turn the crank clockwise and apply a bit of pressure on the drill. (Small drills must be turned rapidly and require very little pressure.)
7. Care must be taken when the drill breaks through the bottom of the hole. Pressure must be released at this point and the drill is eased through the hole gently.

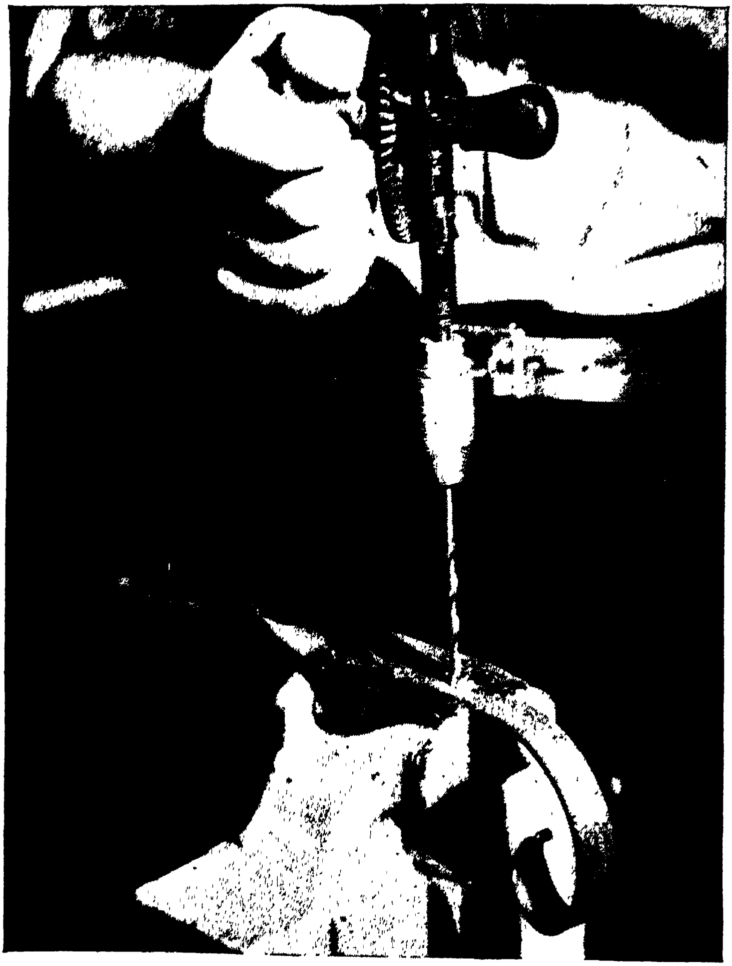


FIG. 41. Drilling a hole in metal using a hand drill.

When drilling a hole more than $\frac{3}{16}''$ diameter, it is good practice to use a power drill. The following rules should be observed:

1. Use a correctly sharpened drill, tightly clamped in the chuck.
2. Do not hold the piece being drilled by hand. Clamp it to the table of the drill press, hold it in a vise, or for small pieces, use a pair of pliers.
3. Make the drill *cut.* It is constructed to take a good shaving at both of its cutting lips. Too little or too much pressure will ruin the drill, and probably the piece also.
4. Use the proper speed.
5. Keep the drill cool with a suitable coolant.
6. Do not drill into pieces that will bend while drilling. This will almost certainly break the drill.
7. Always center-punch the hole position carefully, and if accuracy in positioning is desired, draw a circle with the dividers about one-half the diameter of the drill. As the drill is started in the center-punch mark, this circle will help in determining if the drill is following the mark. If it is found that the drill is not following the center-punch mark, then by tipping the piece slightly or by recenter-punching, the drill point may be made to shift its location in the direction indicated by the circle. For large holes, two or more concentric circles may be used.
8. Test the piece to be drilled with an old file to see if it is hard. If the piece cannot be easily filed, it will ruin the drill.

Fig. 42. A drill cutting correctly.

DRILLING DATA

Material	*Coolant*	*Speed*
Tool steel	Lard Oil	Slow
Mild Steel	Lard Oil	Medium
Brass	Dry or Kerosene	Fast
Nickel	Dry or Kerosene	Fast
Copper	Dry or Kerosene	Fast
Aluminum	Dry or Kerosene	Very fast
Pewter	Dry or Kerosene	Fast
Wood	Dry	Very fast

Grinding.

An *off-hand grinder* is a must in a metal shop. It offers a quick method of sharpening tools such as drills, punches, cold chisels, etc. It also can be used to shape the ends of pieces of band iron before they are bent into a scroll. The work to be ground is held against the wheel at the desired position, and it is supported in the hand or on the rest at a point slightly above the axis of the wheel. The tool rest should be adjusted so that it is about 1/16″ away from the face of the wheel. This will prevent pieces from becoming wedged between the stone and the rest.

The grinding operation, like most other skills, must be practiced before good results can be obtained. The piece being ground is usually hardened steel and must not be heated to the point where its temper will be affected. A light firm pressure with repeated cooling in water is necessary. Never grind soft materials such as wood, lead, or brass on the grinder, because these materials will load up or glaze the wheel and interfere with normal grinding action. The wheel must be periodically dressed with an abrasive stick or other commercial dresser to insure smooth running and efficient grinding.

Bending, Twisting, and Folding Metal.

Most of the bending, twisting, and folding of metal in the craft shop is done while the metal is cold. Bands of metal that are to be bent to form scrolls for various parts of a project are usually formed at the end in order to produce a pleasing finale. Various shapes as illustrated may be used. The flared shape (Fig. 43*B*) requires hammering which will harden the

metal. The ends should then be annealed before atempting to bend the scroll. Some of the above shapes can be formed with a saw and others may be ground on the grindstone or shaped by filing.

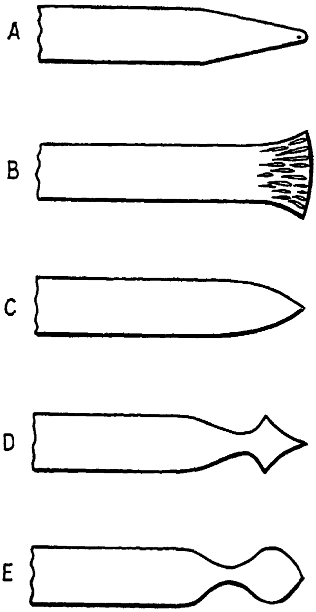


FIG. 43. Various shaped ends for metal bands.

Bending a Scroll. Straps or bands of metal are often required to be bent into circular or irregular curves called *scrolls*. These curves are most easily bent in a jig called a *bending jig*. The theory of this shaping is that a regular curve is made by making a series of uniform bends, in the band, close together. The closer these bends are made to each other, the smaller the radius of the curve. Much care must be taken to continually compare the work with a full-size layout of the curve so that corrections may be made as soon as the curve does not match.

Procedure:

1. Make the full-size layout of the curve required on a piece of paper.
2. Set a pair of dividers at a convenient measurement such as 1″, and step-off the length of the piece with dividers.

3. Cut the stock to length and form the ends as suggested in Fig. 44.
4. Place the bending jig in the vise and adjust it for the thickness of the stock.

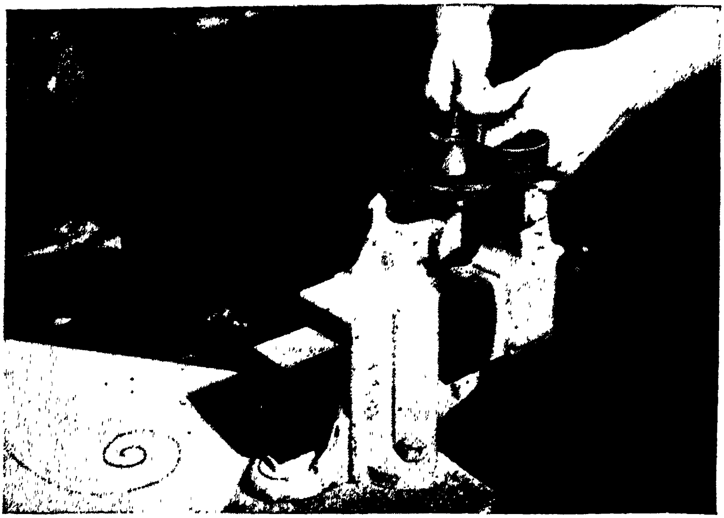


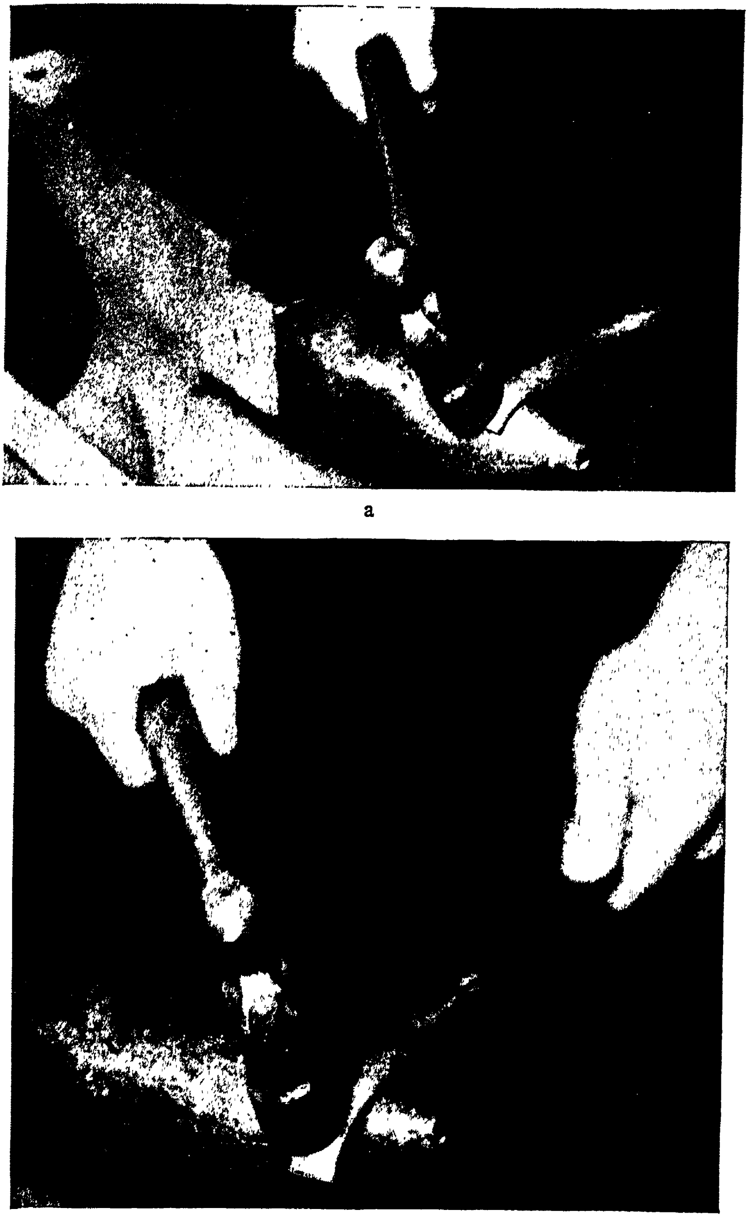
FIG. 44. Bending a scroll using the bending jig.

5. Bend the scroll by starting at one end and bending slightly, then advancing the work slightly. Repeat this bending operation, making successive bends, continuing toward the center of the piece.
6. From time to time, compare the work with the curve required.
7. If there is to be a curve at each end, work from each end toward the center.

Forming a Scroll on Heavier Metal. Heavier metals bend with more difficulty and therefore require heating in order to produce the proper curves. The principal of making a series of short bends on the work and comparing the work with the full-sized layout of the curve is the same as that in the above procedure.

Procedure:

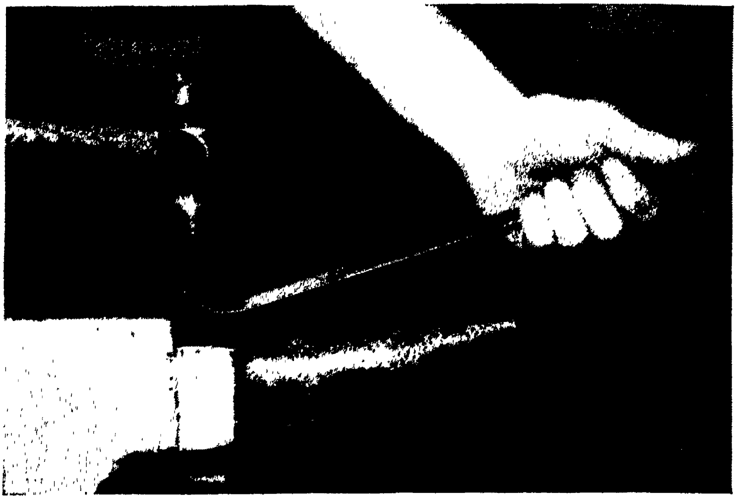
1. Heat the metal in the furnace to a bright red and lay it on the anvil over the horn; form the end of the scroll by striking the work with the hammer at an angle as shown in Fig. 45a.



a

b

FIG. 45. Starting to bend a scroll using hammer and anvil.



a

b

FIG. 46. Completing the scroll using hammer and anvil.

2. Feed the work over the horn of the anvil striking it at the same angle near the horn. (45b.)
3. After the scroll has been started, the work is reheated and placed on the anvil with the curve up, and the end of the curve is closed using light, well-directed blows of the hammer. (46a.)
4. The scroll may then be completed by bending over the horn of the anvil. (46b.)

Making a Twist in a Metal Bar or Band. A pleasing effect may be obtained on band metal work by twisting either a section or the entire piece

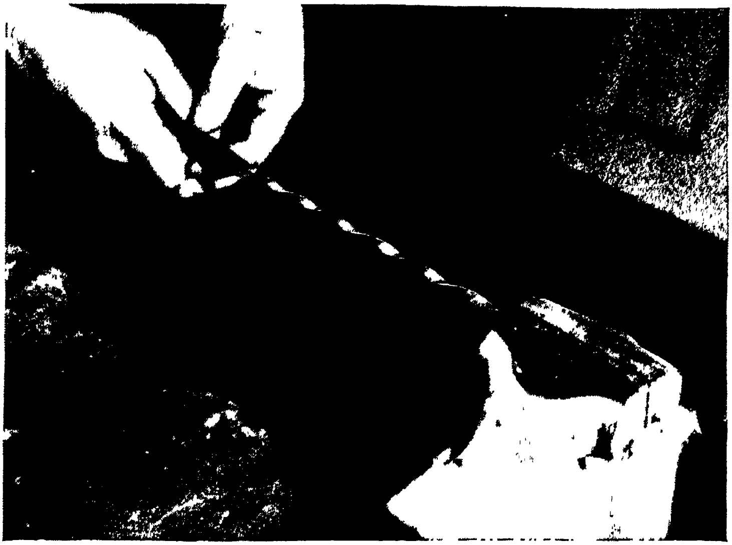


FIG. 47. Twisting a band of thin metal with a pair of pliers.

of work. Bands and squares of any thickness may be twisted successfully. Thin bands of copper, brass or silver can be twisted by holding one end in a machinist's vise and grasping the other end with a pair of square-nose pliers. Holding the metal taut, the pliers are turned until the desired twist is obtained (Fig. 47). A heavier piece of metal may be twisted as follows:

1. Lay out the position of the twist on the metal using a pencil and scales.
2. Place the metal in the vise in a horizontal position so that the mark indicating the start of the twist is in line with the mark.

3. Secure a monkey wrench and close it on the metal at the mark which indicates the end of the twist, and turn the wrench with the right hand, supporting the stock with the other hand.
4. If the twist is to be long, secure a length of pipe which will fit over the twist and use this to keep the twist straight.
5. The twist may be straightened by laying it on a block of wood and hitting with a lead mallet.

Twisting metal adds stiffness to the piece. The stock shortens depending on the number of turns and the cross-sectional shape of the bar. If it is necessary to know the resulting size, test the shortening effect of twisting by using a scrap piece.

Forming a Flat Piece of Metal into a Cylindrical Shape. It is sometimes necessary to form a piece of copper into a cylindrical shape. This operation may be performed either over a stake or other cylindrical form or by using the forming rolls. It is not usually necessary to anneal the metal before it is formed; however, if it is soft, it will bend and hold its shape more readily.

To Form a Cylinder in the Forming Rolls.

Procedure:

1. Adjust the lower roll so that it clears the upper roll by the thickness of the metal being used.
2. Lower the back roll so that the stock will be bent slightly as it is fed between the two front rolls.
3. Feed the stock through the two front rolls adjusting the back roll in a little for each successive feeding.
4. Unlock end bearing cap when cylinder is formed, and slide the cylindrical piece off the top roll.

To Form a Cylinder By Bending Over a Stake.

Procedure:

1. Select a stake or cylindrical form of wood or metal which is slightly smaller than the diameter of the cylinder required.
2. Form the metal over a stake using a fiber mallet and directing blows as indicated in Fig. 49.

To Form a Flat Metal Ring. A flat ring may be formed in much the same manner as explained above. If the metal tends to crinkle, lay it on a flat surface and flatten it by striking it with the mallet.

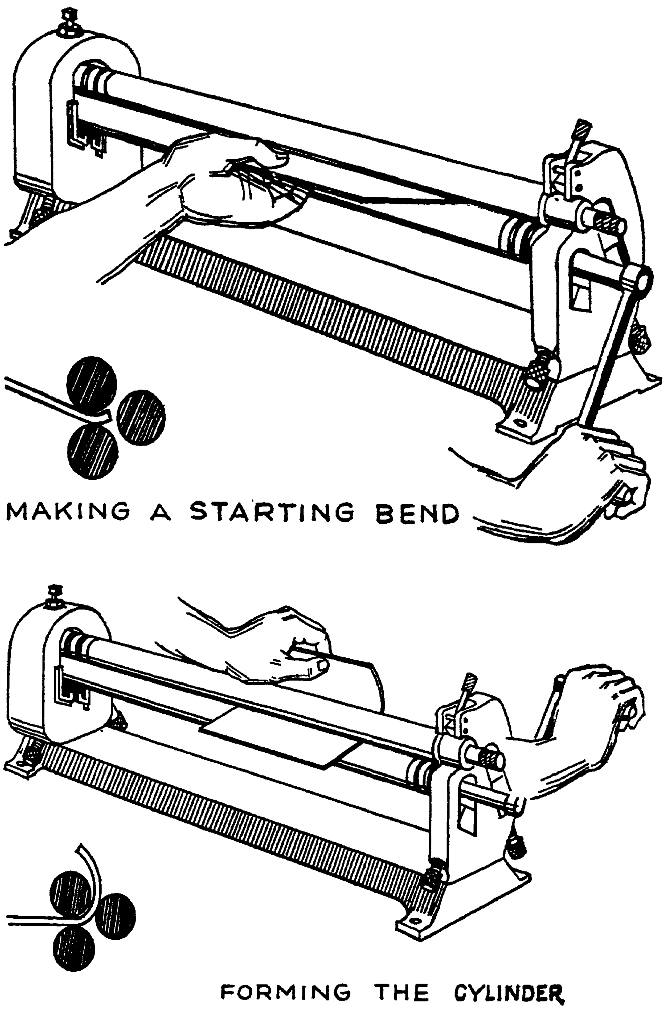


FIG. 48. Use of forming rolls to form a cylinder.

Making a Right-Angle Bend on Sheet Metals. Clean right-angle bends can be made in metal sheets with the use of two blocks of hard wood. The metal is first marked accurately at the place or places at which it is to be bent. If the metal is unusually heavy, it may be scored along the line of the bend with a blunt, cold chisel. This scoring should be done on the inside of the corner bend. The metal is placed in the vise between the two

Fig. 49. Forming a cylinder using mallet and stake.

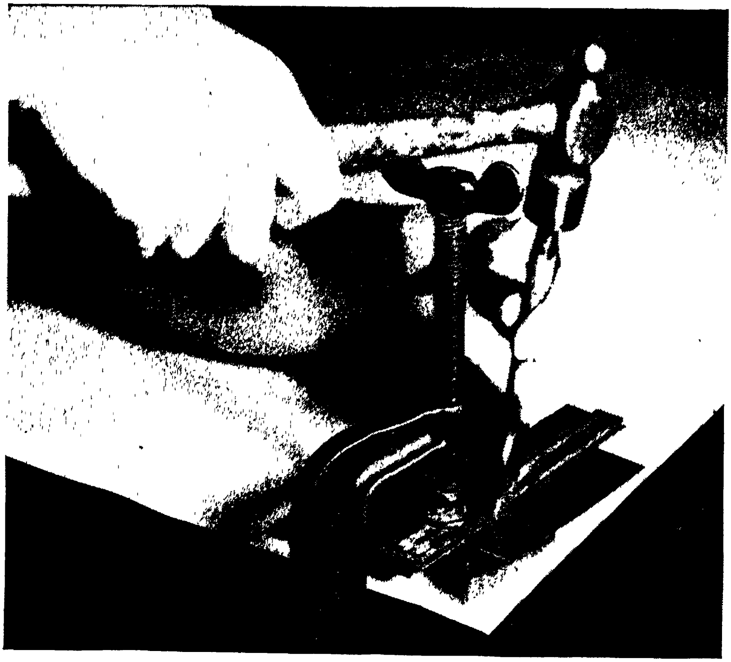


Fig. 50a. Scoring a line along the bend with a cold chisel

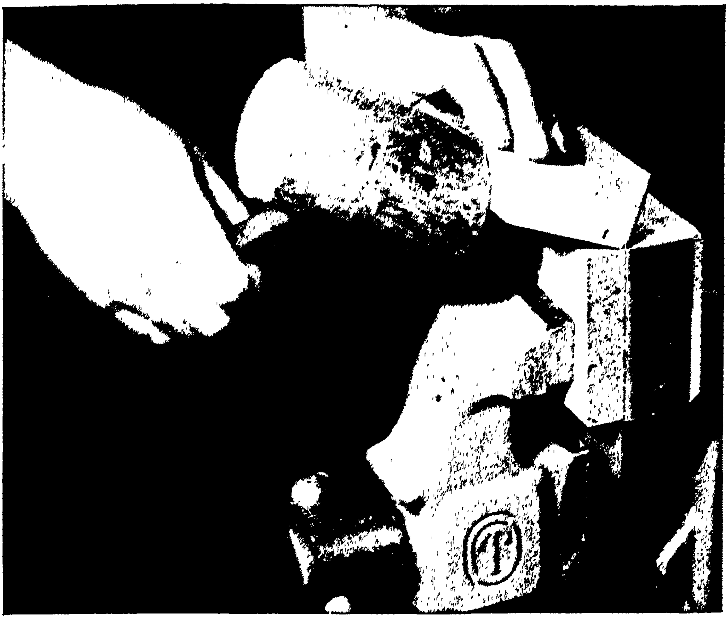


FIG. 50b. Bending the corner between blocks of wood held in the vise.

blocks of hard wood, lining up the edges of the wood with the mark on the metal. The metal is then bent carefully using a third piece of wood to back up the piece being bent. If it is desired to make several bends in the metal such as is required in a metal box, the blocks should be prepared for the size of the inside of the box. The blocks are then placed on the metal and clamped in a vise. The bends are made in the manner described above.

A bend is sometimes required on the edge of a disc of metal. Two circular forms are prepared of hard wood and the metal disc is clamped between them in the correct position. The edge is then bent over the form by using a mallet. Care must be taken not to bend the metal too fast. The metal will bend best if it is formed over the wooden block in three or four successive stages. The first stage should start the bend at about 20 or 25 degrees; each time around the circle the mallet strikes at less of an angle bending the metal nearer the form. The last time around the metal is brought up tight against the form.

FIG. 51. Bending a flange on the edge of a circular disc over a form.

Folding Seams on the Bar Folder. The bar folder may be used to fold a straight edge on a piece of flat sheet metal for the purpose of forming a seam. It is also used for producing a hem on the edge of the metal in order to strengthen the work and produce a smooth rounded edge.

Procedure for making a hem:

1. Cut out the required material allowing extra for the hemmed edge.
2. Set the bar folder for the size of hem.
3. Place the metal in the bar folder and fold the metal as far as possible.
4. Place the metal (hem up) on the top plate of the bar folder and bring the folder over to set the hem down tight.
5. If a double hem is required, set the machine for a slightly deeper hem, and repeat the above operations.

Making a Grooved Seam.

Procedure:

1. Obtain a hand groover of the required size.

2. Make the layout and cut out the metal, allowing three times the width of the groove size for the seam.
3. Cut two small scrap pieces of metal about 2″ x 3″ and the same thickness as is to be used in the project.
4. Set the bar folder slightly less than the width of the groove in the hand groover that is to be used.
5. Fold each of the scrap pieces.
6. Hook the two folds together and strike the seam lightly with a mallet.
7. Lock the seam using the hand groover and hammer. (If the seam does not lock properly, readjust the bar folder and proceed again with the scrap pieces until the seam will lock properly.)
8. Fold the seam on the project. (If the piece is to be formed into a cylinder, fold the seam in opposite directions on the flat sheet.)
9. Lock the seam with a hand groover and a hammer.

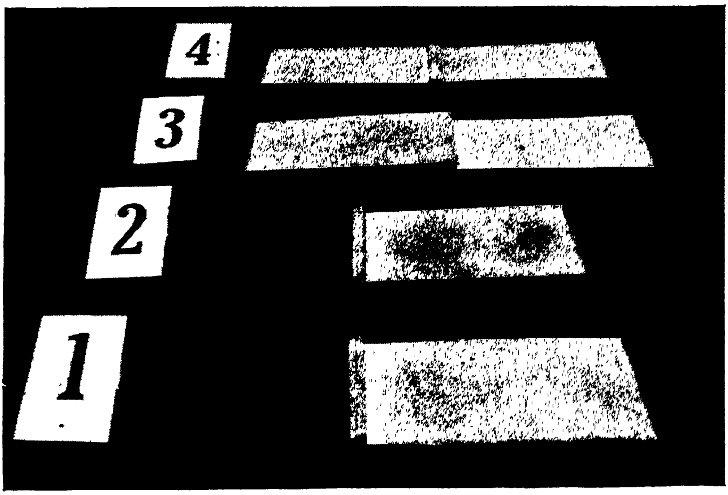


FIG. 52. Making a grooved seam.

1. One edge folded.
2. Second edge folded in opposite direction for cylindrical work.
3. Folds hooked together.
4. Seam locked with hand groover.

Wire Edge. It is sometimes advisable to insert a wire in the edge of a piece of sheet metal which is to be formed into a cylinder. The wire edge

will strengthen the top of the object and will also produce a neat, rolled edge appearance. The following procedure is recommended:

1. Select a suitable size wire and cut it slightly longer than the circumference of the cylinder, using side-cutting pliers.
2. Make the layout for the cylinder, allowing an amount equal to 2½ times the diameter of the wire for the seam.
3. Using a scrap piece for a test, set the bar folder so that the radius of the fold is the correct size for the wire.
4. Using a test piece, adjust the bar folder to fold just enough metal to completely cover the wire.
5. Insert the stock in the bar folder and fold for the wire.
6. Straighten the wire with a mallet and insert the wire in the groove provided.
7. Form the metal over the wire with a wedge-shaped mallet or setting hammer.
8. Cut the wire to length and proceed rolling the stock to a cylindrical shape in the forming rolls. The wire edge should be placed in the groove in the lower roll of the forming rolls.

Etching.

Etching is the process of removing metal by chemical means in order to produce a surface design. The portions of the design which are to be eaten away are left exposed to the action of the acid, while all other surfaces are covered with an acid resist which protects them from the acid. The success in etching a design on metal depends a great deal on the preparation of a clean blank and the exercise of care in painting the design. The procedure used to produce an etched design on an article made from copper, brass, German silver, pewter, or aluminum is as follows:

1. Select an area type design which has little or no fine, thin-line detail.
2. Trace or draw this design full-size on a piece of paper.
3. Clean the surface of the metal on which the design is to be etched with steel wool and paint it with whiting. (Whiting may be made by mixing one part whiting, five parts water, five parts alcohol and a few drops of liquid soap.)
4. When the whiting is dry, transfer the design on the metal, using carbon paper (Fig. 53).
5. With a fine scratch awl, scratch the design into the metal. Scratch only deep enough so that the design may be seen when the whiting

FIG. 53. Transferring the design on the metal.

is removed (Fig. 54). Avoid unnecessary lines as they will be difficult to remove later.

6. Wash off the whiting with water and clean both sides of the metal with fine steel wool. Avoid handling surfaces which have been cleaned.

FIG. 54. Scratching the design into the metal.

7. Lay the face of the piece on clean paper and paint the back and edges of the metal with black asphaltum varnish, being careful to cover the metal completely.
8. Cut a piece of cardboard slightly larger than the metal and, when the varnish has become tacky, place the cardboard on the varnished surface and turn the metal over.
9. Paint all the surfaces of the design which are to be protected from the acid (Fig. 55). Allow the asphaltum to dry overnight.

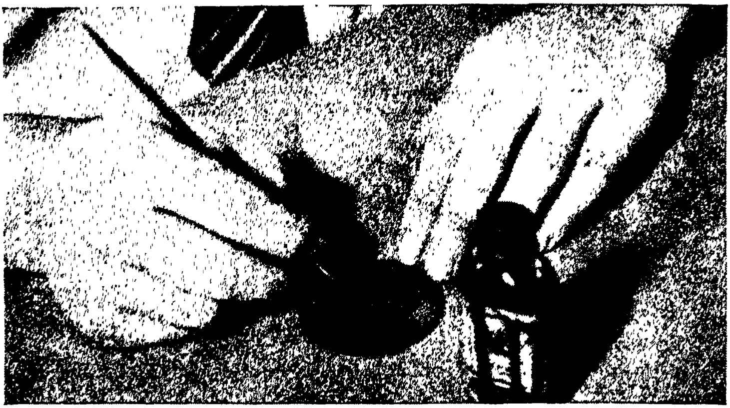


FIG. 55. Painting the design.

10. Examine the work for spots which are not covered with asphaltum. Touch up if necessary.
11. Place the work in the proper etching solution and allow the surface to etch. For a clean-cut, even etch, bubbles may be brushed from the surface of the metal with a feather. The length of time required for etching depends on the strength of the acid, the temperature of the acid, and the kind of metal. Inspect the progress every 10 minutes, and remove the work from the acid if any asphaltum is being lifted by the acid. If the depth of the etched design is not deep enough, the parts may be repainted and, after dry, the work may be placed in the acid again.
12. When the surface is sufficiently etched, remove the work from the acid and wash thoroughly in water.
13. Remove the asphaltum varnish with turpentine or lacquer thinner.

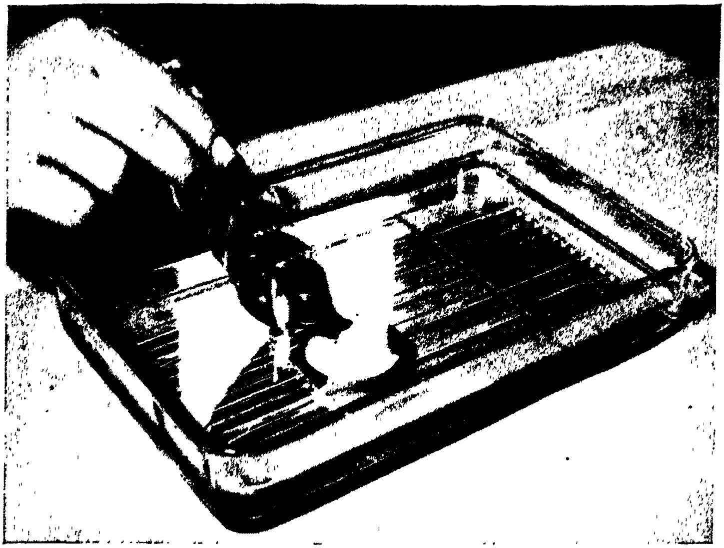


FIG. 56. Etching the design.

Etching Solutions:

Etching solution for *copper or brass*:
To three parts of water, add one part nitric acid.
Etching solution for *German silver*, and *pewter*:
To four or five parts water, add one part nitric acid.
Etching solution for *aluminum*:
To three parts water, add one part hydrochloric acid.

Caution: Always add the acid to water, never the water to acid, as steam is generated and will cause a small explosion.

Heat Treatment.

Annealing is the process of softening metal by heat treatment. All the metals used in the metalcraft shop are hardened by mechanical means, such as hammering, bending or rolling. If the metal is allowed to harden, further working may cause the metal to crack because of strains set up in the hardening process. The size of the work to be annealed will determine the source of heat needed for annealing. A Bunsen burner may be a sufficient source of heat for small work. A soldering furnace or blow torch may be necessary for larger work. Avoid placing the work in a soldering fur-

nace without protecting the work from the dirt at the bottom of the furnace.

Copper, brass, German silver, and sterling silver may be annealed by heating uniformly to a red heat and quenching in water or pickling solution.

Aluminum may be annealed by heating slowly over a flame until a drop of oil, placed on its surface, reaches its flash point. Aluminum requires no pickling.

Pewter generally requires no annealing.

Tool steel is hardened by heating the piece to a "cherry red" (about 1375° F.) and quenching it in oil.

Tempering is a process which reduces the hardness and brittleness of hardened steel by reheating to the proper temperature, according to the hardness desired, and then dipping the steel in water. The proper temperature for the required hardness may be determined by watching the colors which form on the surface of the steel as the temperature is raised. It is necessary to polish the surface of the part with abrasive cloth before tempering so that the colors can be seen more easily. A chart of colors for hardening various common tools follows. Care must be taken to reheat rather slowly, so that the proper color can be determined.

TEMPERING COLORS FOR VARIOUS TOOLS

Tools	*Color*	*Temperature (° F.)*
Scrapers, engraving tools	None appears	200 (about the boiling point of water)
Awls, punches, chasing tools	Straw yellow	450
Plane iron and twist drills	Brown yellow	500
Hammers	Brown yellow	500
Cold chisels	Brown purple	550
Knives, screwdrivers, saws	Red purple	575
Springs	Blue	580–600

Steel is annealed by heating it to "cherry red" and cooling slowly. The slower the cooling, the softer the steel will become. It is good practice to allow the steel to cool with the furnace as it cools.

Pickling.

Pickling, in metalcraft, is a term given to the process of removing oxides, which form on the metal when it is being heated, by the use of acid. The

acid dissolves the oxides which are formed on the metal surface and aids in the cleaning of the surface of the work with abrasive before it is polished. Pickling acid should be kept in a glass container large enough to handle the bulk of work to be done in the shop. A jar of water near the pickling acid is handy to use as a rinse, and an alkaline neutralizer in a third jar may be used to neutralize the action of the pickling acid.

Pickling Solution. To make up a pickling solution for copper, brass, and German silver:

To twenty parts of water, add one part sulphuric acid and stir with a wooden stick.

Caution: Always add the acid to water; never the water to acid.

Neutralizing. A saturate solution of sodium bicarbonate and water will make an effective neutralizer.

Procedure:

1. After annealing, plunge the red-hot metal into the pickling solution. (Stand back at arm's length from the pickling solution.)
2. After a minute or two, remove the object from the acid with a piece of wood or pick-up tongs.
3. Rinse the metal in water and dip it in the neutralizer.
4. Rinse again in water and dry the metal with a clean rag.

Cold pickling will remove oxides but requires more time than heated work. Extreme care must be taken when working around acids to see that none splashes on the body or clothing. Tools must be kept away from acids and acid fumes to prevent corrosion.

Tooling Metal Foil.

Thin sheet copper or brass foil can be tooled in order to produce a three-dimensional design on its surface. This medium is excellent for craft work where a minimum of equipment is available. Either 34 or 36 B & S gage metal is the most satisfactory. A leather-working *modeling tool* is ideal for this work; however, an orange stick or a dowel rod, shaped to resemble a thumb on one end and pointed like a pencil at the other, will do. The ends of the tool must be smooth.

Procedure:

1. Select a suitable subject for the design. Pictures of landscapes are in general too complicated for this kind of treatment. The human figure is an excellent subject if the composition lends itself to outlining

and does not require too much detail work. Flowers are usually workable subjects. Newspapers and magazines abound with suitable material.

2. Cut the sheet metal to the desired size with scissors and smooth it out with a wooden rubbing tool (a small sandpapered flat piece) on a glass slab. Be sure to leave sufficient border space.
3. Whiten the back surface of the copper with a solution made of 1 part whiting, 5 parts water, 1 part alcohol, and a drop or two of liquid soap. Trace the design on the whitened surface with a dull-pointed tool. Another method is to fasten the paper, carrying the design, onto the back of the metal sheet and trace the design with a dull point directly into the metal. Use only a light pressure for the design lines.
4. Place the metal foil on the felt pad and go over the outline with a *tracer* or blunt-pointed wooden tool.
5. The metal foil is then placed with the front side down on a felt pad, and those portions of the design that are to be raised are gradually pushed into the pad. The pressure is applied on the inside of the outlines with the small modeling tool, being careful to keep the outlines distinct. The modeling tool is moved with firm straight or circular strokes, and with moderate pressure in the areas to be raised. Do a little at a time, and be sure not to push the surface out too far, as they cannot be molded back, and too much stretching may rupture the metal. A *ball end* or *deer foot* modeler will help in getting into narrow spaces.
6. After the work is partially done, turn the metal over, and press the background and borders around the raised portions down on a glass slab or piece of hard wood, to keep the outlines clear and the background in the original plane.
7. At this point the background may be stippled by tapping with a blunt tool in order to provide a pleasing contrast. Take care not to put a hole through the thin metal.
8. After the design is all done, it is a good plan to fill the depressed portions on the back with a material which will harden and so prevent the thin metal from denting. Many commercial compounds are available but a simple, effective one may be made by mixing plaster of Paris and metal lacquer to a thick consistency. Clean the depressions in the work and apply a coat of metal lacquer. Fill the depressions with the filler and allow to dry in a horizontal position for

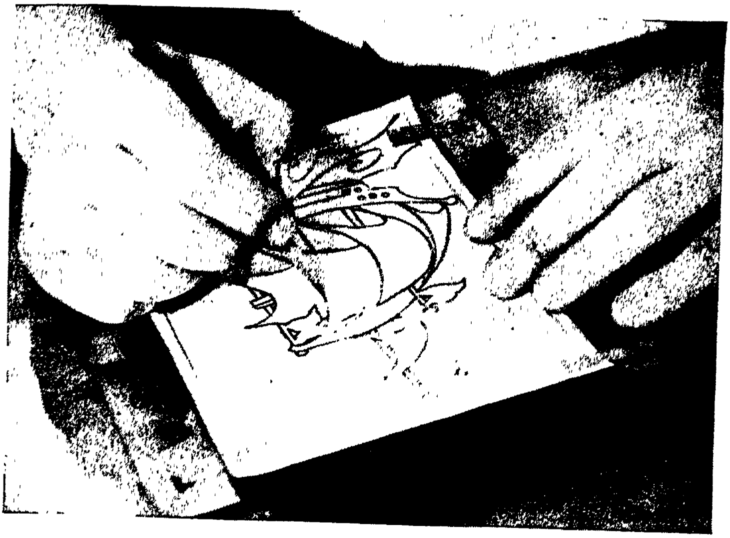


FIG. 57a. Trace the design on the metal with a hard pencil.

FIG. 57b. Outline the design with the tracer end of the modeling tool.

FIG. 57c. Raise the design from the back with the spoon end of the modeling tool.

FIG. 57d. The work is placed on a glass slab to press the background in the original plane.

FIG. 57e. The background may be stippled in order to provide a contrast.

at least 24 hours. The picture is then fastened to a wooden piece with small brass nails called *escutcheon pins.*

9. Finish by polishing and lacquering or by antiquing and waxing.

Soldering.

Soldering is classified as being either hard or soft, depending on the type of solder which is used. A joint soldered with hard solder is stronger than one soldered with soft solder; however, soft solder is more easily used. In soldering, the heat is produced either directly on the metal as with a torch or Bunsen burner or indirectly with a soldering copper. In all soldering, there are four important factors which must be observed in order to produce a neat, strong joint:

(1) The work to be soldered must be cleaned with meticulous care.

(2) The proper flux and solder for the particular metal must be used.

(3) The metal must be heated to a temperature slightly higher than the melting point of the solder being used.

(4) The solder must be allowed to cool slowly.

The function of a flux in soldering is to prevent oxidation when heat is applied. When a piece of bright copper is heated over a flame the surface will quickly become dull in appearance. A bit of flux on the dulled surface will brighten it so that the solder will flow freely. Aluminum is a metal whose surface oxidizes most readily and therefore is most difficult to solder A special flux and solder are necessary when soldering aluminum.

Soldering with a Soldering Iron. In order to obtain good results when using a soldering iron, it must first be tinned. Tinning the soldering iron is the process of getting the solder to stick to the point of the soldering iron. To tin a soldering iron, follow the procedure outlined below:

1. Clamp the soldering iron in a vise and file the four sides of the point until the copper is clean and bright. A piece of abrasive cloth fastened to a block of hard wood will work well in place of a file.
2. Place the cleaned iron in the soldering furnace and heat it a little above the melting point of solder. Avoid placing the soldering iron directly in the flame. Test the heat of the iron with a piece of solder.
3. The iron is then cleaned chemically by one of the following methods:
   a. Rub the heated soldering iron on a block of sal-ammoniac and touch it with solder.
   b. Prepare a saturate solution of sal ammoniac powder (ammonium chloride) and water. Dip the tip of hot soldering iron in this solution and touch it with a piece of solder.
   c. Dip the point of the heated soldering iron in rosin paste flux and touch it with solder.
   d. Prepare a "dip" by mixing a commercial soldering salt as directed on the container, and use as above.

To Solder a Joint Using the Soldering Iron.

Procedure:

1. Clean the surfaces of the metal to be soldered using steel wool. Some metals require more cleaning than others. Tin plate should be cleaned very lightly, if at all, as the plating will be removed if much abrasion is used. Copper, brass, German silver, aluminum, and pewter may be cleaned with steel wool whereas iron or steel must be cleaned by using abrasive cloth or filing.
2. Select a soldering iron large enough for the job. A small iron will not give sufficient heat for soldering a piece having a large surface.
3. Arrange the work in a convenient position on a piece of clean asbestos

(transite) board or some material which will not absorb the heat from the iron.

4. Apply the flux to the metal at the joint.
5. Tin the soldering iron as explained above.
6. If the joint is long, "tack" it in several places in order to hold it in position.
7. Place the heated soldering copper on the work and feed the solder to the tinned tip, allowing the metal to heat so that the solder flows from the heated iron to the joint. Hold the piece down with the tang of a file or some other tool if there is a tendency for the metal to shift as it is being soldered.
8. Move the soldering iron along the seam at a speed that will preheat the metal ahead of it so that the solder will flow into the joint. As the solder is being used, feed solder to the iron at the tip.

Fig. 58. Soldering a joint with a soldering iron.

Clamping and Wiring Work to be Soldered. The method used in holding pieces to be soldered will vary depending upon the size, shape, and placement of the work which is to be soldered. Most pieces are best held with annealed iron wire. The joint is first fitted carefully after which each piece is cleaned near the joint with steel wool and the pieces are tied to-

gether with iron binding wire. Wire of a gage strong enough to hold the pieces securely should be used. The wire is tightened by twisting the ends together until the joint is brought in place.

For some pieces on small work, a small cotter pin or bobby pin can be used to good advantage as a clamp to hold pieces to be soldered. There is a metal clamp on the market which is much like a spring-type clothespin which is handy for clamping larger work. Small "C" clamps are also handy for sweat-soldering flat pieces.

Soft-Soldering with Direct Heat. Soft-soldering is usually done with solder made of 50 per cent tin and 50 per cent lead which melts at approximately 414° F. A good form of solder to use when soldering with direct heat is a wire solder. The wire can easily be cut into small pellets and placed on the joint. It is essential that the work be cleaned and that the proper flux be used. The source of heat may be a Bunsen burner, a blow torch, or an alcohol lamp.

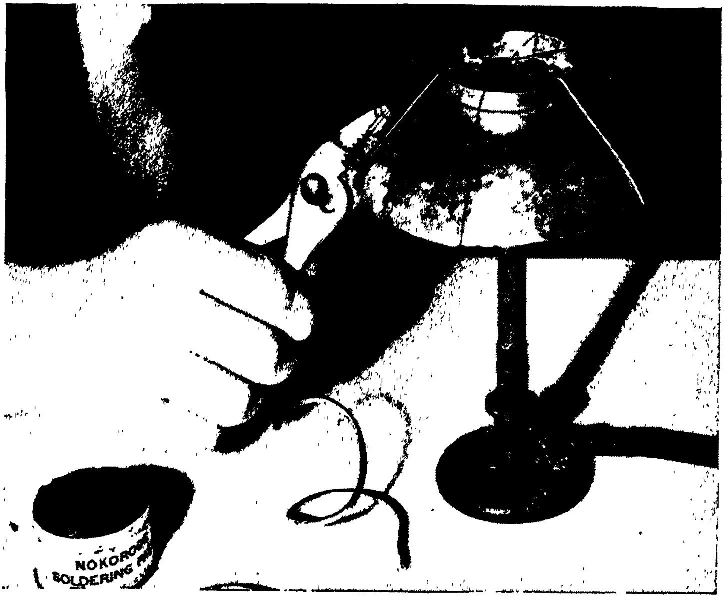


FIG. 59. Soldering with a Bunsen burner.

Procedure:

1. Clean the pieces to be soldered thoroughly.
2. Wire or clamp the pieces in place.

3. Apply flux to the joint to be soldered.
4. Prepare small pieces of solder and place them along the joint.
5. Apply the heat in such a way that both pieces to be soldered heat evenly. (Large area pieces need more heat.)
6. Allow the flux to boil and the solder to melt and run into the joint.
7. Allow piece to cool, wash off excess flux with soap and water, and remove wire or clamps.

Sweat Soldering Two Pieces of Metal.

Two pieces of metal can be sweat-soldered together in much the same manner as one glues two pieces of wood. This process is used when the joint surface is large enough to produce a strong seam and when it is desirable to solder without allowing the solder to be seen.

Procedure:

1. Clean both pieces thoroughly.
2. Apply flux to each piece and heat the smaller of the two with a flame until solder melts on the piece.
3. Touch a piece of solder to the surface and allow the solder to run on the entire surface of the piece. Use a piece of steel wool to spread the solder evenly. This process is known as tinning.
4. If the second piece to be soldered is identical in shape, the above procedure is repeated. If the second piece is larger than the first, it does not need to be completely tinned. Take care to keep the solder hidden as it is difficult to remove.
5. Clean the surfaces of the pieces again and apply flux again to each.
6. Clamp or wire the pieces together.
7. Heat the pieces until the solder has melted. A piece of solder may be used to test the heat by touching it to the clamp. (If the solder melts, the correct heat has been reached.)

Soldering Pewter.

Pewter, because of its low melting temperature, is more difficult to solder. It is soldered best with a special low melting point solder known as pewter solder. The best form for use is the wire solder. It may be flattened into a thin ribbon by hammering. A special flux is used as described in the preceding chapter. A small flame on the Bunsen burner or an alcohol lamp will be sufficient for all work.

Procedure:

1. Clean the joint with steel wool.
2. Clamp or wire the work. (Pewter is heavy enough to be soldered without wiring or clamping in some instances.)
3. Apply pewter flux to the joint and place a series of small pellets, cut from the pewter solder, on the joint.
4. Heat the joint carefully. Apply the heat by moving the flame along the joint, watching the solder. The moment the solder melts, withdraw the flame. (Take care not to overheat small sections. Apply the heat in such a way as to heat both pieces equally.)
5. Allow the work to cool slowly, remove clamps or wire, and wash off excess flux with soap and water.

Fastening Work with Rivets.

Rivets used in the metalcraft shop are generally of the round-head type and are either finished by filing flush after heading over in a countersunk hole or by forming a rounded head. The rounded head may improve the appearance of the job if it is hammered with the ball end of the ball peen hammer. This peening process produces a series of facets which may be desirable. A rivet set may be used in some cases to produce a smooth round-head on the rivet. Rivets may be made of the same material as the work being riveted or may be of a contrasting metal.

Procedure:

1. Locate the position of the rivets on the metal.
2. Drill the hole for the first rivet in both pieces. Holes in thin sheet metal may be punched with a solid punch rather than drilling.
3. Place the rivet in the hole and cut it off so that it extends through the metal a distance about equal to the diameter of the rivet.
4. Clamp the proper size rivet set in the vise and hold the work so that the head of the rivet fits into the spherical depression in the rivet set.
5. Strike the rivet with the face of the hammer in order to "upset" the rivet so that it fits tightly into the hole prepared for it.
6. Head the rivet over with the ball end of the hammer, directing the blows in such a way as to form a uniform rounded head.
7. If the rivet is to be headed with a rivet set, a second rivet set is placed over the rivet after the rivet has been upset, and the rivet set is then struck with the hammer until the rounded head is formed.

Care must be taken not to mar the surface of the metal being riveted with the rivet set.

8. After the first rivet is secured, the holes for the remaining rivets are drilled or punched and the above procedure is repeated.

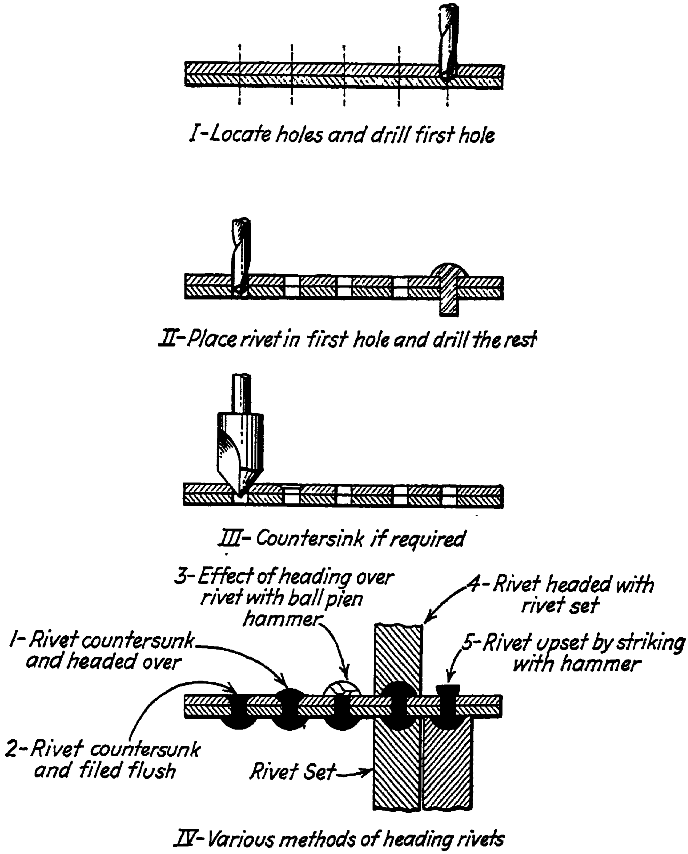


FIG. 60. Fastening two pieces of metal with rivets.

When riveting work that cannot be held on the rivet set because of its shape, the riveting can be done on the horn of an anvil, a stake, or a piece of metal especially prepared for the work, held in a machinist's vise.

Flush riveting may be done on thick metal by countersinking the hole slightly and heading the rivet over as explained above. The rivet is then filed flush with the surface.

Internal and External Threads.

In order to produce an internal thread for fastening with a machine screw or stove bolt, a hole must be first drilled of the proper size. This hole is called the *tap hole* and is drilled with a *tap-drill.* A tap-drill is an ordinary drill of the proper size for the particular tap to be used. If possible, the hole to be threaded should extend entirely through the work as a blind hole is more likely to cause breakage of taps. The tap is held and turned with a tap wrench. Care must be used in selection of a tap wrench of a convenient size in order to start the tap straight. Cutting oil is used when cutting threads on all metals except cast iron.

The tap-drill size is determined by using a table or, if none is available, it may be figured by subtracting the reciprocal of the number of threads per inch from the outside diameter of the thread.

Example: Tap size 3/8-16 (The 3/8 is the nominal size of the screw and 16 is the number of threads per inch.)

$$3/8 - 1/16 = 5/16 \text{ tap drill size}$$

A common thread to be cut in metalcraft work is the 1/8-27 N.P.T. which is a standard pipe thread used on most lamp sockets. Pipe-thread tap-drill sizes must be determined by table because the nominal size of pipe is a good deal smaller than the actual outside diameter of the pipe.

To drill and tap a hole, use the following procedure:

1. Locate the hole to be threaded and center-punch it.
2. Determine the size of the screw to be used and select the proper size tap drill.
3. Drill the tap hole.
4. Place the work in a horizontal position in the bench vise.
5. Place the proper size tap in the tap wrench and start the tap by turning it clockwise into the hole. Take care to hold the tap in line with the axis of the hole being tapped.
6. Use cutting oil and continue turning the tap until a complete thread is obtained.
7. Remove the tap by turning it counterclockwise.

A taper or plug tap is used in threading a through hole. A blind hole must be finished by using a bottom tap.

External threads are cut on cylindrical stock by the use of a die and die stock. The procedure is more simple than cutting an internal thread. The outside diameter of the rod determines the size of die to be used. Pipe threads are cut with special dies which cut a slightly tapered thread

on pipe. The size of the pipe die to be used on a given size pipe is the nominal size of the pipe. This is slightly larger than the inside diameter of the pipe for most sizes.

The following is the step-by-step procedure to be used in cutting an external thread with a die.

Procedure:

1. Grind or file a slight chamfer on the end of the rod or pipe that is to be threaded. This permits the die to start easily.
2. Select the proper size die for the job and place it in the die stock.
3. Note the starting side of the die. (The side which has only partial threads cut in the hole.)
4. Place the stock in the vise, holding it in either a vertical or horizontal position.
5. With the starting side of the die facing the work, start the thread by turning the die stock slowly in a clockwise direction, keeping a firm pressure against the work. Care must be taken to hold the stock at a right angle to the axis of the work being threaded.
6. After the thread is "caught," squirt a generous amount of cutting oil over the die and work and continue turning the stock, backing off about one-quarter turn after every half turn, in order to break off chips.

If it is required to rethread a rod in order to produce a more perfect thread, care must be taken not to "cross-thread" the piece when starting the die. A "drunken" thread is caused by starting the die obliquely rather than square. Drunken threads are often the result of trying to start a die straight on a rod that was not cut off square.

Sinking a Well or Depression in a Tray.

To sink a well or depression in a tray, one of two methods may be used. A tray form may be used in which a depression is provided the exact shape and size required. This form may be made of metal or hard wood. The wooden form is not as permanent; however, it can be made up quickly for use if a wood turning lathe is available. Metal forms may be purchased at a metalcraft supply house.

A partial form may be used for the purpose of sinking a well in a tray. This form is usually made of maple or birch. It may be cut to the contour of the tray in order to obtain a uniform depth in the well. This method of sinking is usually used on trays of large diameters.

Forming a Tray in a Mold.

Procedure:

1. Select a tray mold of a desirable shape for the job on hand.
2. Measure the diameter of the recess in the mold and cut a circular disc of metal to fit exactly into this recess.
3. Select a wooden or leather-tipped mallet which will conform to the contour of the recess in the mold.
4. If the metal to be used is hard, anneal it.
5. Hold the disc in the mold with the left hand and start beating the metal with the mallet near the edge of the well.
6. The edge of the well will appear on the disc. This will provide a guide for directing successive blows.
7. Rotate the mold, beating the metal toward the side of the well, thus

FIG. 61. Sinking a well in a tray with a mallet.

drawing the metal down into the well. (Do not beat metal on the bottom of the mold, direct the blows toward the side of the well, working gradually deeper in the form.)

8. Anneal the tray once for every quarter of an inch of sinking. Take care to keep the rim of the tray flat; use a rawhide mallet to flatten the rim if it begins to wrinkle.
9. When the well is sunk to the bottom of the mold, a piece of hard wood, formed to the shape of the contour of the well, may be used with a mallet to iron out irregularities in the tray.

Forming a Tray Using a Block of Wood Held in the Vise.

Procedure:

1. Prepare a block of hard wood cut to the shape of the contour of the well in the tray.
2. Drive two nails in the block to act as stops for the edge of the tray.
3. Cut a circular disc of metal the size required for the tray and anneal the disc, if necessary.

FIG. 62. Wooden stake used in sinking a well in a tray.

4. Scribe a circle on the disc as a guide to locate where the well begins.
5. Select a raising hammer whose shape most nearly fits the shape required.
6. Hold the disc in the left hand and strike lightly just inside the well line, rotating the disc slowly.
7. Turn the tray upside-down on the bench and straigthen the rim using a block of hard wood and a mallet.
8. Anneal the tray as required.
9. Repeat the sinking until the well is the required depth.

FIG. 63. Sinking a well in a tray using wooden stake.

Raising a Bowl.

A bowl is one of the most useful and ornamental objects made in the metalcraft shop. Raising is the process of forming a bowl from a flat disc of metal by beating it into a shallow depression formed in the end grain

of a block of wood or by forming it over a stake, using a raising hammer or mallet. For the beginner, it is advisable to limit the design and size of the bowl in order to first master the process of low raising. A bowl made from a disc not more than 6″ in diameter is not too difficult for a beginner to attempt. The art of raising a bowl, unlike most work in metal, does not necessarily limit a person to exacting dimensions. The design often is developed while working on the metal, much as the potter forms the clay on a potter's wheel. However, the beginner should limit the depth of the bowl to one-third the diameter of the original disc and the contour should conform to a curve on a planishing stake in order that the planishing may be done with ease. For a description of planishing see page 92.

Raising a Shallow Bowl.

In shallow raising, the material for the depth is secured by stretching the metal in the raising process. The metal becomes thinner as the bowl becomes deeper. It is therefore good practice to use a fairly heavy gage metal for this type of work. In this process, because of the stretching, the diameter of the original disc need be only slightly more than the diameter of the top of the finished bowl.

Procedure:

1. Cut the circular disc.
2. Anneal the disc.
3. Form a slight hollow by beating a depression in the end grain of a block of hard wood or on the surface of a rectangular block of lead with a raising hammer.
4. Clamp the block in a machinist's vise and start to raise the bowl, using a ball peen hammer or a raising hammer; begin raising along the outer edge. Rotate the disc while hammering and strike the metal with even blows.
5. Anneal the metal as it becomes hard and unyielding. Annealing is usually necessary once for each ¼″ of depth obtained.
6. Work in concentric circles toward the center of the disc. More depth may be obtained by repeating the above operations. Smoothness is not of major importance; however, care must be taken to maintain a uniform shape.
7. Correcting the uniformity of contour may be done by directing hammer blows at flattened areas. Deep indentations may be removed by

inverting the bowl on a stake and hammering these dents out with a wooden or rawhide mallet.

8. The bowl is now ready for *finishing* or further shaping such as *flaring, fluting,* or *bottoming.* These processes are explained in another section of this chapter.

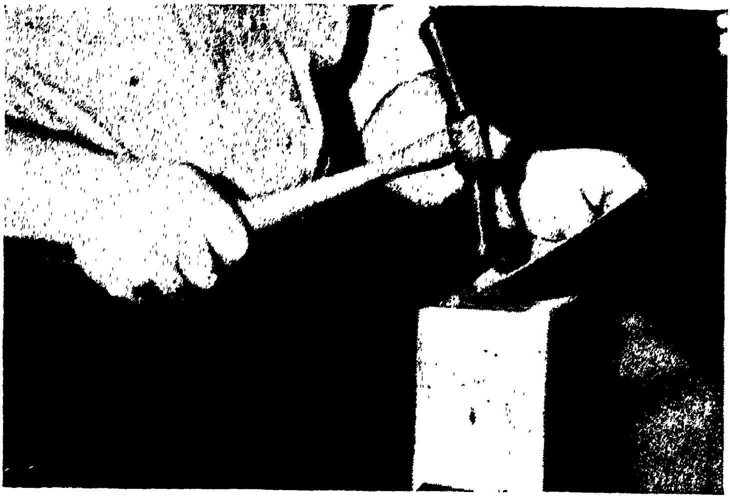


FIG. 64. Raising a bowl using a raising hammer and a block of hard wood.

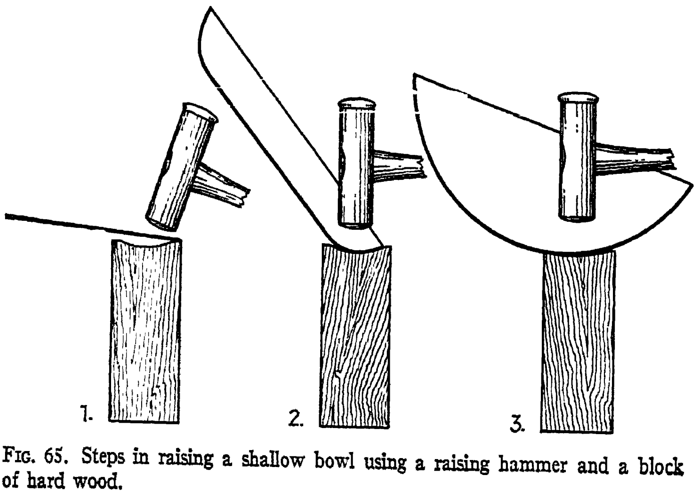


FIG. 65. Steps in raising a shallow bowl using a raising hammer and a block of hard wood.

Raising a Deep Bowl.

Deep raising is a method of shaping a hollow vessel of greater depth than that described above. In this process, most of the hammering is done on the outside of the vessel and the metal is not thinned as it is in sinking or shallow raising. The diameter of the disc required is determined by adding the height of the vessel to the largest diameter. The beginner should limit himself to a beginning disc of not more than 6″ or 7″ in order to master the techniques before attempting something more difficult. The process of planishing may be simplified if the shape of the vessel is made to conform to the contour of a single stake that is on hand in the craft shop.

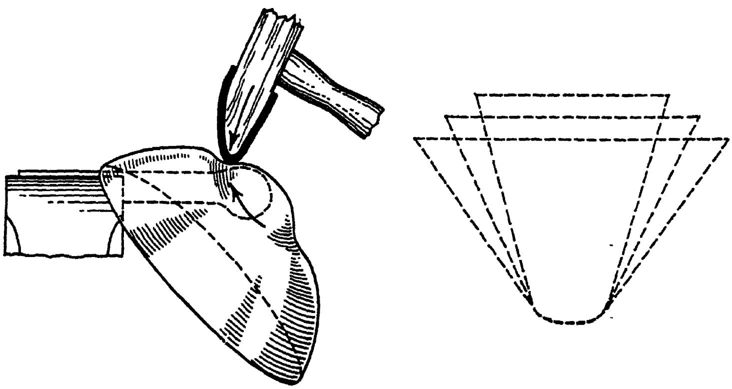


FIG. 66. Raising a deep bowl over a stake.

Procedure:

1. Cut a circular disc of the diameter required.
2. Anneal the disc.
3. Begin to raise the disc as described in the preceding process: "Raising a Shallow Bowl."
4. Clamp a "T" stake horizontally in the vise and hold the work over the end of the stake at a slight angle.
5. With a raising hammer or a wedge-shaped wooden mallet, strike the metal slightly above the point where the metal makes contact with the stake. Rotate the work, forming the metal, above the point of contact, down on the stake.
6. After one rotation, continue a second course by moving the work and directing the blows slightly above the first course.

Caution: Frequent annealing is essential. The work cannot be raised too quickly as crowding of the metal will cause cracks. If cracks appear they may be soldered with a hard solder which does not discolor the copper.

7. It is a good plan to mark a circle around the vessel after each annealing to guide the hammer blows for the next course.
8. On the last course, where the metal is driven down directly on the stake, a wooden mallet is used instead of a hammer.
9. After the top course is reached, the vessel may be corrected by testing its contour with a template made from a piece of stiff cardboard, and by forming areas which do not conform to contour of the template.
10. The vessel is now smoothed over a stake, using a fiber mallet. It is then ready for *planishing* or further shaping such as *flaring* or *bottoming*.

Flaring.

The rim of a vase, bowl, or other vessel may be flared by forming the metal over a wooden block prepared with a rounded edge to conform with the desired curve. Place two flat-head nails in the flaring block to act as guides for the metal and gradually form the flare by striking the edge with

FIG. 67. Flaring the edge of a bowl.

a rawhide or leather-tipped mallet. Rotate the work on the wooden stake as the blows are directed on the edge of the work. Annealing must be done as soon as the metal does not yield to the action of the mallet. In flaring as in raising, if the bowl is to be finished by planishing, one must keep in mind the shape of planishing stakes which are available and work to a curve that will fit over the planishing stake.

Planishing.

Planishing is the process of producing a series of highly polished facets on a metal surface by striking the surface of the metal, as it is being held on a planishing block or stake, with the highly polished face of a planishing hammer. Planishing hardens and stiffens the metal; therefore, it enables the object to retain its shape better. The size of the facet produced by planishing depends on the radius of the face on the planishing hammer and the curvature of the work. Usually a planishing hammer has one face with more of a spherical curve than the other. Some planishing hammers have a face which is absolutely flat. This face is only for planishing work which has a convex surface.

Good results in planishing depend to a great extent on preparation of the work and tools. The work must be cleaned thoroughly before planishing. It is not necessary to remove deep scratches; however, the work should be pickled and all loose scale from all surfaces must be removed with steel wool. The planishing hammer, stake, or block must be polished to a mirror-like surface. Any imperfection in the surface of the planishing hammer, stake or block will imprint itself in every facet that is made with the hammer.

Preparing the Planishing Stake, Hammer, or Block.

Procedure:

1. Clamp the tool whose planishing surface is to be polished, in a machinist's vise.
2. Remove deep scratches with No. 120 grit abrasive cloth, working the cloth over the surface in the same manner as you buff a pair of shoes. Use a bit of cutting oil on the abrasive to help the polishing action.
3. When the deep scratches have been removed, follow with a piece of No. 180 grit abrasive cloth. Polish until the scratches made with the No. 120 grit have disappeared.
4. Continue with No. 240 abrasive and then repeat with No. 320 abrasive cloth.

5. Bring the surface to a mirror-like polish with a piece of crocus cloth or polish the surface on a buffing machine using a felt wheel and jeweler's rouge.
   Note: Care must be taken to remove all deep scratches with the coarser abrasives before advancing to the finer.

FIG. 68. Repairing planishing hammer and stake.

Planishing.

Procedure:

1. Select a stake which most nearly conforms to the contour of the work. (Flat work is planished on a flat planishing block.)
2. Select a hammer and try it out on a scrap of metal to determine the size of the facet produced.
3. Polish the hammer and stake as outlined above.
4. Clean the metal of oxides by pickling and cleaning thoroughly with steel wool.
5. On circular work, start in the center and planish in concentric circles, working toward the outer circumference.
6. Take care that the metal is held in contact with the stake at the point where the hammer is to strike. The hammer should hit the

metal squarely in order to avoid unsightly marks from the corner of the hammer. The facets formed by the hammer should be uniform and should overlap slightly.

7. Clean the planished surface with fine steel wool and inspect it for "holidays" (places which have been overlooked). Replanish the surface in areas where necessary.

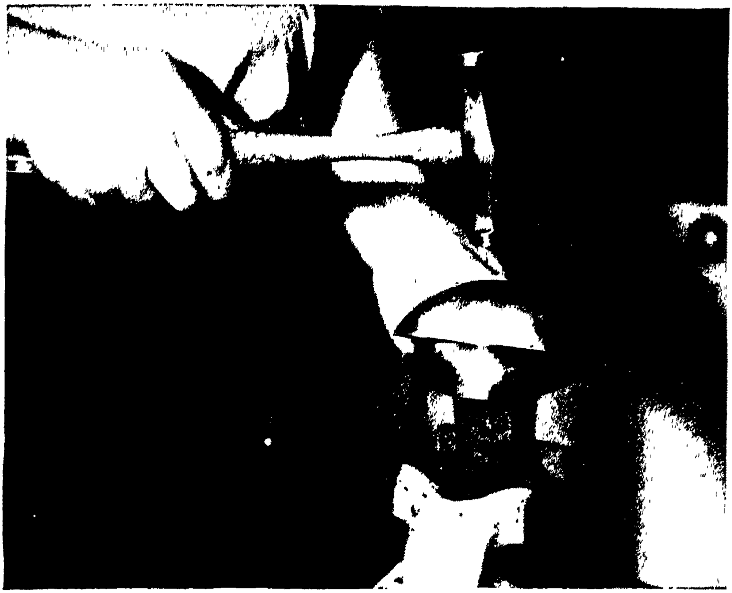


FIG. 69. Planishing over a stake.

Planishing may be done with a ball peen hammer if the ball is properly prepared. The small facets produced by the ball peen hammer, however, require more work in hammering and therefore are not satisfactory for large areas. Normally, it is not necessary to anneal the work during or after the planishing operation.

Fluting.

An effective method of decorating a shallow bowl or the rim of a plate or tray is by fluting. Fluting is the process of embossing shallow, straight-lined, radial depressions in a piece of metal. When the flute is depressed from the outside of the bowl or the bottom of the rim of a plate or tray, it

is known as concave fluting. Work that is fluted in the reverse is called convex fluting. In general, it is easier to prepare tools for concave fluting.

Before the fluting is done, a fluting block is made of a piece of maple or other hard, close-grained wood. This block is formed to fit the contour of the work. A V-shaped groove is filed in the block to the depth required. A wedge-shaped fluting tool is prepared of hard wood. This tool is used to drive the metal down into the groove.

Procedure:

1. Divide the circumference of the work into any number of equal parts as required.
2. Draw radial lines on the outside of the work with a pencil, indicating the location of flutes.
3. Place the fluting stake in a machinist's vise.
4. The work is held in position on the stake, lining up the groove in the stake with the pencil mark on the work. (This requires the assistance of a second person.)

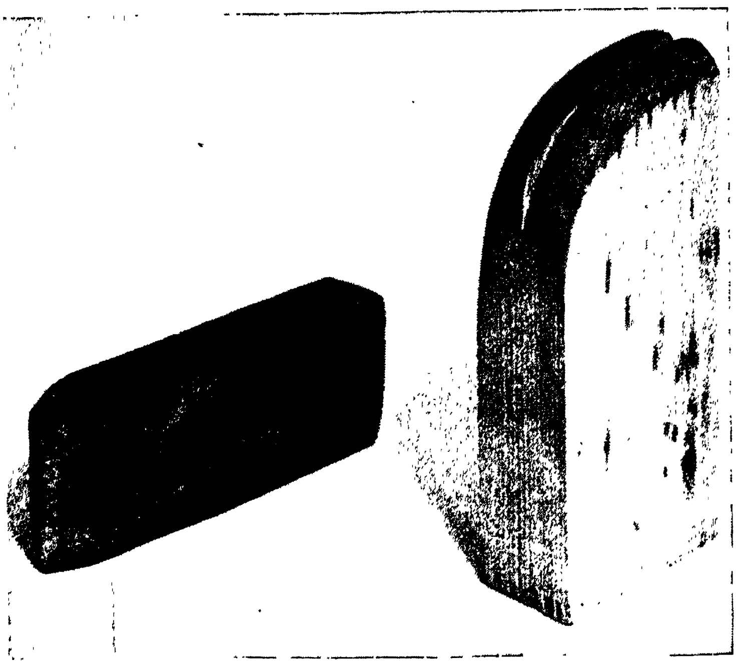


FIG. 70. Fluting tools.

5. Holding the wedged tool in the left hand and a hammer or mallet in the right, the metal is driven into the groove in the stake (Fig. 71).
6. The above operation is repeated on the remaining radial lines, taking care to make each of uniform depth and size.

FIG. 71. Forming the flutes.

Note: Fluting seldom requires annealing and may be done directly after the planishing or bottoming operation.

Bottoming.

In order for the bowl, tray, or vessel to set in position on a flat surface, it must be provided with a flat bottom, or some suitable base or foot must be fastened to it. Flat bottoms are formed on the work after the planishing operation.

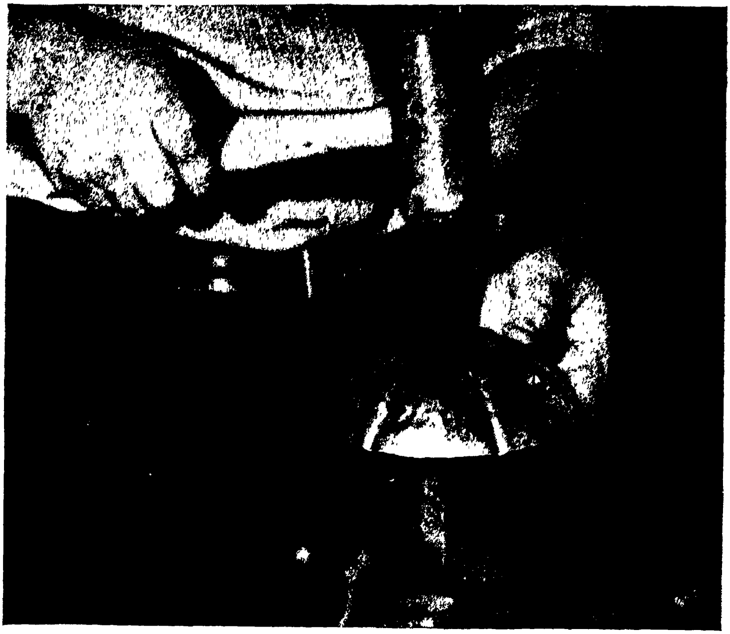


FIG. 72a. Flattening the bottom.

Procedure:

1. Select a bottoming stake or a round piece of cold-rolled steel whose diameter is equal to the diameter of the bottom as required. If cold-rolled steel is used, the surface should be smooth, and the sharp corners should be rounded with a file.
2. Mark a circle on the inside of the bowl representing the bottom.
3. Place the work on a sandbag, hold the bottoming stake in place, and

strike the stake with a mallet in order to mark the bottom circle on the outside surface.

4. Place the stake in a machinist's vise, invert the bowl on the stake, and flatten the bottom using a rawhide mallet. Take care to hold the bowl in place as indicated by the mark from the previous operation.
5. A bottom shoulder is formed with a sharp wedge-shaped mallet, or a necking hammer striking the work slightly outside the stake edge.

FIG. 72b. Forming a shoulder on the bottom.

Trueing Up.

After the forming has been completed and the bottom is formed or the foot is fastened to the bowl, the irregular top edge is "trued up" so that it will set level. This is accomplished by holding the object securely on a flat metal plate and, with a surface gage adjusted to the proper height, a line is scratched around the work near the top. The excess metal is then trimmed off with a pair of snips and the edge is finished with a file. An effective substitution for a surface gage may be made by using a pencil and a block of wood of the proper height.

Repoussé Work or Chasing.

Chasing is a means of decorating metal work to give it a tooled effect. The work is done on the reverse side of the material, for the most part, by means of chasing tools which are made in many shapes and forms. *Repoussé,* as chasing work is often called, is an art which was mastered by metalcraftsmen in early history. It is sometimes referred to as sculpture work in metal, as it gives the flat surface of sheet metal a three-dimensional effect.

Chasing tools of various sizes and shapes have been discussed in Chapter 2; however, it might be a good plan for the beginner to make himself a few of the more common tools for his own use. A drawing and directions for making these tools are included in the following chapter.

The procedure used in chasing is similar to that used in the tooling of metal foil, the main difference being that the metal used in chasing is heavier than the foil and therefore requires more pressure to shape it. Simple designs, such as flowers or leaves, lend themselves to this three-dimensional modeling. The metal is held in chaser's pitch which may be kept in a metal pan or, for small work, the pitch is held in a semi-spherical pitch block which is held in a chaser's ring. The chaser's ring is a metal or leather ring which enables the chasing block to be held in various positions while the chasing is being done. As in other fields of metalcraft work, chasing requires a great deal of practice. The beginner should limit himself to simple designs on small work. For most work, No. 20 B & S gage soft copper is satisfactory. The work is usually done on a piece slightly larger than the design and trimmed after it is removed from the pitch; however, this is not always the practice.

FIG. 73. Proper position used in holding the tracer when chasing.

Procedure:

1. Anneal a piece of 20 gage copper which is large enough for the design.
2. Bend the corners of the metal under with a pair of pliers and moisten the back of the piece with a drop of oil.
3. Place the metal on the pitch with the corners down and begin to warm the pitch slowly with the flame of a blow pipe or Bunsen burner. Too much heat may cause the piece to sink too deep in the pitch.
4. When the pitch becomes plastic, press the work down firmly into the surface of the pitch.
5. Cool the work and pitch under running water.
6. Trace or draw the design on the metal.
7. Select one or more tracers from the chasing tool assortment and a light chasing hammer.
8. Hold the chasing tool in the left hand and start to chase along the lines drawn on the metal surface. Hold the tracing tool tilted slightly away from the direction in which it is moving as you work it along the outline (Fig. 73). Rest the third and fourth finger on the metal in order to steady the tool and move it evenly along the line. Use a straight tracer for straight and slightly curved lines and a curved chaser for curves of small radii.
9. After the complete design has been traced, remove the work by heating and lifting it with a pair of pliers.
10. Anneal the work and clean it with turpentine.
11. Bend under the edges in the opposite direction, apply a drop of oil, and set the metal in the pitch in the reverse position.
12. Using the round and oval planishers, while the pitch is still warm, raise the areas within the outline.
13. The work is then removed and reversed again for a final tooling to produce the desired effect. Care must be taken when reinserting the work to have the entire design filled with pitch since air bubbles may form and not back the work sufficiently for further chasing. When the design is raised unusually deep, the hot pitch may be poured into the deep places in order to eliminate trouble from these air pockets; matting tools may be used in order to obtain a contrasting background.

FIG. 74. Raising the design from the reverse side.

Polishing and Finishing Metals.

Buffing. The nonferrous metals used in the metalcraft shop are usually polished to a mirror-like luster on a buffing lathe; however, in order to produce a good polished finish on any metal surface, the underlying principle of polishing must be understood. One may consider the polishing operations as beginning with the final pickling and cleaning of the metal which prepares the surface for planishing. Planishing is a surface-finishing operation which in turn leaves only minor imperfections which may be removed on the buffing lathe.

Procedure:

1. If the surface has been oxidized by heating, pickle the metal after its last heating. (See *Pickling procedure.*)
2. Clean the oxides off the metal with steel wool or pumice stone.
3. If work is to be planished, planish the surface. (See *Planishing procedure.*)
4. If the work is to have an unplanished, polished surface, remove deep scratches with a coarse abrasive cloth starting with an abrasive coarse enough to remove the deepest scratches. Remove the marks made with the coarse abrasive with the next finer abrasive thus grading the abrasives used from coarse to fine, removing abrasive scratches made with one grit, with the next finer grit. Do not try to remove deep scratches with too fine an abrasive. The abrasive equipment may be stored in an envelope for reuse at a later date. It is not necessary to polish planished surfaces with abrasive cloth as the planishing should remove all the deep marks from the surface of the metal.
5. Nonferrous metals may be polished further by using a fine and extra-fine grade of steel wool.
6. Select a coarse muslin buffing wheel for the buffing lathe and screw it on the taped arbor. (Notice that the left-hand arbor of the buffing lathe has a left-hand thread which allows the buffing wheel to advance on the arbor as it is rotated counterclockwise.)
7. Protect your eyes and face with an eyeshield or goggles.
8. Start the machine and apply a coarse buffing compound to the *bottom* of the revolving wheel. *Emery paste* is especially good for polishing iron or steel; *Tripoli composition* is good for preliminary polishing of copper, brass, bronze, German silver, and other nonfer-

rous metals; *white diamond dust composition* may be used on the above metals when only one buffing operation is to be used.

9. A hard felt wheel may be used on certain work where a considerable amount of "cutting down" is necessary. Any of the above compounds are used on the felt wheel.
10. If it is desired to produce more of a luster on the polished surface, a fine, loosely stitched cotton buff is placed on the machine. This fine buff is used only with jeweler's rouge compound and should be kept free from all other abrasives. Buffing with this compound is the final polishing operation and will not remove scratches. Its action is a rubbing action rather than that of cutting or scratching.

Too much polishing compound on the wheel will cause the wheel to deposit some of the compound on the surface of the work. Too little pressure will produce the same effect. Care must be taken to allow the rotating wheel to work off the edges of the metal. If the wheel is allowed to run onto the edge of the metal, the work will catch and may be thrown from the wheel.

Various scratch brushes may be used on the buffing lathe in order to produce finishes such as a *brush finish, satin finish* or *matt surface.* These finishes depend on the size of the wire in the brush and the material which is used for the wire in the brush. No compound is used with these brushes.

Preserving the Surface. Most metals are affected by the action of various gasses in the atmosphere. Highly polished copper and brass will discolor rapidly and should be protected with a good grade of metal lacquer. Other highly polished metals may either be lacquered or waxed. A good grade of paste wax is effective for use on surfaces which are chemically colored. A decidedly more permanent result may be obtained by applying one or more coats of a good grade of metal lacquer. If the surface is waxed, it may need to be renewed in two or three weeks.

Lacquering. Clear metal lacquer may be applied to metal surfaces to prevent oxidation. In order to obtain best results, a fine ox-hair, sign painter's brush may be used. The metal must first be washed, preferably with lacquer thinner and allowed to dry without touching its surface with the fingers. Lacquer, as it comes from the can is generally too thick for immediate use and therefore should be thinned so that it will flow freely as it is brushed on the surface. Lacquer must be brushed on quickly and should not be gone over with the brush after it is applied, as it becomes tacky almost immediately. Care must be taken to spread the coating evenly on the surface and not to leave any "holidays" which will tarnish quickly

and produce an unsightly dark mark on the surface. If you are not satisfied with the results at the first attempt, remove the lacquer with *lacqucr thinner* and repeat the operation. Lacquered work cannot be repolished unless all the lacquer is first removed with its solvent. Lacquer usually dries enough for light handling in fifteen or twenty minutes.

Chemical Finishes.

Oxidized Surface. Perhaps the simplest chemical means of coloring a surface is to heat the metal and allow the oxygen in the air to form a layer of oxides on the surface. The surface of the metal must be cleaned by buffing or with steel wool and oil or grease must be removed with soap and water or some other grease solvent before this process is attempted. As the temperature is raised, the colors change, beginning with a pale yellow and changing progressively through brown, purple, and blue to a dull varigated surface. Practically all metals may be colored in this manner, but some of the colors are very hard to preserve. The surface must be protected by wax or lacquer after the desired color is obtained. Some experimentation with sample pieces will be necessary to obtain the desired effect. It will be found that the wax or lacquer will affect, and in some cases entirely change, the color produced by heating.

Antiqued Surface. An excellent antique effect may be obtained on copper, brass, and German silver by mixing a small amount of *liver of sulphur* with water. This solution may be applied either hot or cold with a brush or a swab made by twisting a bit of cotton waste about a stick of wood. Be sure that the surface of the metal is clean. It is a good plan to test the solution on a scrap piece of metal and then add more water or liver of sulphur as needed. Highlights may be rubbed on the surface with very fine steel wool after the work is dry. The work is then protected with wax.

Other chemical coloring agents for various metals are listed below. The chemicals may be bought at any drugstore.

As the proportions given for the solutions are more or less theoretical, the following round figures, which are easier to remember, may be used:

30 grams = 1 ounce
1 liter = 1 quart

To Color Copper or Brass Green or Antique Green

Cupric nitrate	$Cu(NO_3)2$		40 grams
Ammonium chloride	NH_4Cl		40 grams
Calcium chloride	$CaCl_2, 2H_2O$		40 grams
Add distilled water	H_2O	To make	1 liter

Brush onto a clean surface.

To Color Copper Blue or Purple

Sodium hyposulphate	$NaHSO_2$		60 grams
Nitric acid	HNO_3 (Conc.)		4 grams
Add distilled water	H_2O	To make	1 liter

Dip metal into this solution.

To Color Copper Black

Potassium sulphide	K_2S		15 grams
Ammonium chloride	NH_4Cl		200 grams
Add distilled water		To make	1 liter

Dip metal into this solution.

To Color Iron or Steel Black

Sodium thiosulphate	$Na_2S_2O_3$		3 grams
Add distilled water.	H_2O	To make	1 liter
	(Temperature of solution 200° F.)		

To Color Iron or Steel Blue

Sodium bisulphite	$NaHSO_3$		60 grams
Lead acetate	$Pb(C_2H_3O_2)_2$		15 grams
Add distilled water	H_2O	To make	1 liter
Dip metal into this solution.	(Temperature of solution 200° F.)		

Miscellaneous Finishes.

Polished surfaces on iron or steel are usually obtained by a process of draw filing and then polishing with emery cloth wrapped around the file to provide an even pressure. Oil is often used with fine emery cloth for the final finish. For a good luster after all the scratches have been removed, crocus cloth is used in the same manner as emery cloth.

Steel wool may be used to impart a fairly bright finish to the softer metals such as aluminum, pewter, and lead. The finer the steel wool the smoother will be the finish.

An attractive dull satin finish may be obtained by rubbing the metal surface with a coarse brush dipped in a mixture of pumice and water.

The circular spotted finish often seen on metal surfaces may be produced by the use of a wooden or fiber rod held on the chuck of the drill press. The end of the rod is charged by dipping into a mixture of fine emery and oil, and the revolving rod is brought down on to the metal surface to form a regular pattern of spots.

Foundry Work.

Foundry work is the term given to the making of castings by pouring molten metal into a mold. Molds used for some of the lower melting-point metals may be made of metal. Such molds are called permanent molds and may be reused repeatedly and indefinitely. When only a few castings are to be made or when casting metals of high melting points, the mold is made of sand. The discussion of foundry work in this book will be limited to making castings in sand.

If the craft shop is equipped with a three-burner soldering furnace, this furnace can be used to melt aluminum and aluminum alloys and also zinc and zinc alloys which melt at a lower temperature. Scrap pewter pieces make excellent metal for casting at a much lower melting point.

Numerous metal objects may be collected which make excellent patterns for metal casting. Such objects as book ends and wall plaques are especially adapted to molding in sand. Be sure that the pattern selected has sufficient draft or taper to allow it to be drawn from the mold without disturbing the sand. If the metal pattern is large enough, a hole is drilled and threaded at a point which will be convenient for inserting a lifting screw when removing the pattern from the mold. Small patterns can be lifted from the mold with tweezers.

Ramming Up a Mold.

Procedure:

1. Temper the molding sand by adding water and mixing thoroughly until the sand will stick together when it is squeezed in the hand. The lump should be tested to see that sharp corners are left when the piece is broken with the hands.
2. Place the pattern on the molding board. If the pattern is a split pattern, use the half without the dowel pins.
3. Invert the drag and place it over the molding board. Sift a small amount of parting sand over the pattern.
4. Riddle enough molding sand in the drag to cover the pattern.

FIG. 75. Testing the temper of the sand.

FIG. 76. Riddling sand to cover the patterns.

5. Fill the drag full of unsifted sand and ram the sand first with the peen and then the butt of the rammer.
6. "Strike-off" the excess sand with a strike-off iron.
7. Place the second molding board on the drag, invert the drag and remove the first molding board.

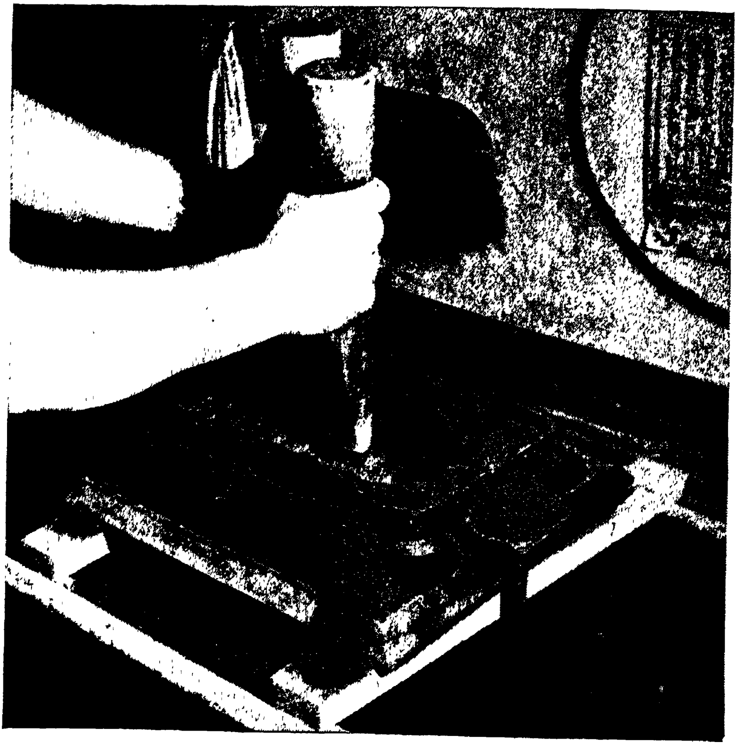


FIG. 77. "Ramming-up" the drag.

8. Dust off parting sand with bellows and place second half of split pattern in position.
9. Set the cope on the drag, place the sprue pins in position on opposite sides of the pattern so that metal will run quickly into all parts of the mold. Sprue holes may be cut later with a sprue cutter if sprue pins are not used.
10. Sift parting sand over the mold, riddle enough sand to cover the

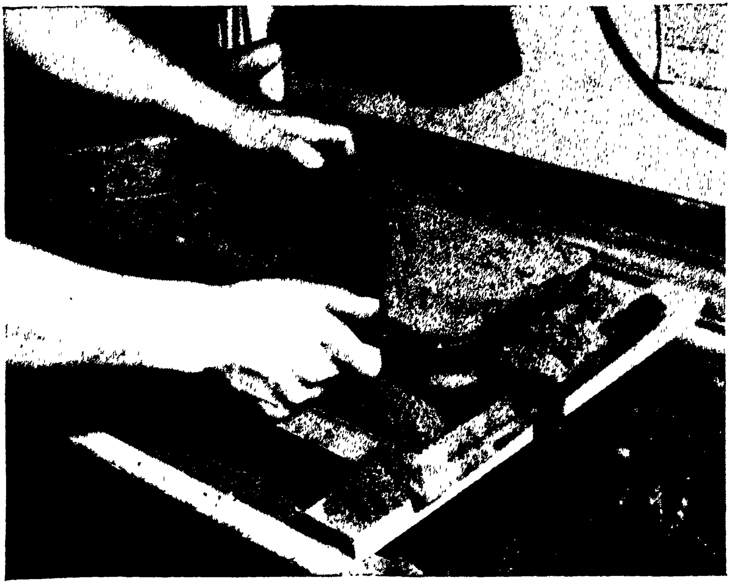
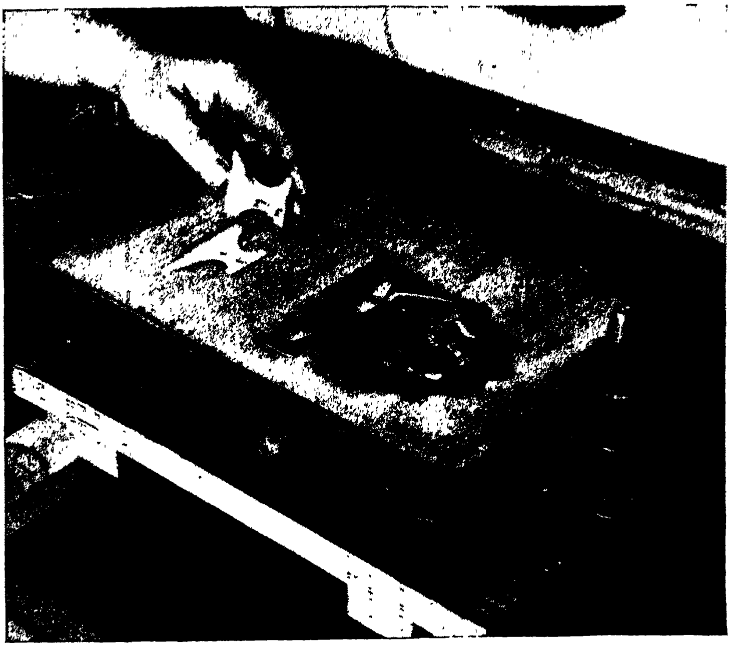


Fig. 78. "Striking-off" excess sand.



pattern, fill the cope with unsifted sand, and ram up the cope, not quite as "tight" as the drag.

11. "Strike-off" the cope and remove the sprue pins. With the fingers or a slick, round the sharp corners of the top of the sprue hole so no loose sand will enter the mold when it is poured. Sprue holes may be cut at this time with a sprue cutter.

FIG. 80. Cutting sprue holes with sprue cutter.

12. Remove the cope from the drag and invert it on a molding board.
13. With a bulb sponge, dampen the sand around the edge of the pattern.
14. Drive the lifter into the wooden pattern or screw the lifter into the metal pattern. Rap the pattern lightly with the rapper.
15. Lift the pattern from the mold.

16. Cut the gate, with a gate cutter, from the mold to each sprue hole. The gate should be wide and should deepen as it advances toward the sprue hole.
17. Carefully blow out the loose particles of sand and repair the mold with slick and spoon if necessary.

Fig. 81. "Rapping" the pattern.

18. Replace the cope on the drag, and weight the mold to keep the metal from leaking out at the parting of the flasks.
19. Melt the metal to be used and pour the mold. Enough metal should be available to fill the mold and sprue. The sprue through which the metal is to be poured is called the "pour hole"; the other is called the "riser." Some molds may have more than one pour hole and riser.

A good number of the difficulties encountered by the beginner may be attributed to improper tempering of the sand. Gases which are formed in sand that is tempered with too much water will create an extreme pressure when the molten metal is poured. This pressure produces blow holes and gas pockets in the casting. Overheated metal also causes excess gasses. The metal, in most instances, should be poured soon after it melts. Be sure

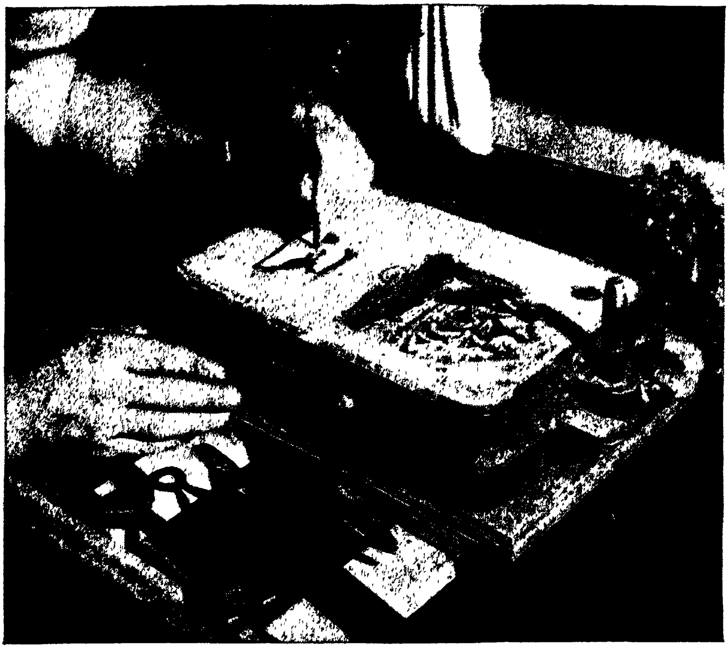


Fig. 82. "Lifting" the pattern.

there is enough metal in the ladle for the casting being poured. Loose sand in the sprue or gate may flow into the mold, thus causing sand holes in the casting. A shallow, concave depression on the top of the casting usually indicates shrinkage and can be corrected by using more or larger sprues and gates which will feed the casting as it shrinks. If the mold does not completely fill with the molten metal, the metal may not be hot enough and may have frozen before it has filled the mold. Another cause of failure is that the gate may be so small that the metal solidifies here before it reaches the mold.

Caution: When handling molten metal, always heat the ladle before it is placed in the melting pot as a cold ladle may cause an explosion of the molten metal if it is used without heating.

After the casting has solidified, break up the mold, cut off the sprue with a hack saw, file the rough edges, and finish the casting. Pewter, aluminum, and zinc alloys will take a fine polish if the procedure as outlined under "Polishing" and "Finishing Metals" is followed.

FIG. 83. Castings removed from the mould.

Metal Spinning

Speeds used in metal spinning may vary between 300 RPM and 3000 RPM. These speeds depend somewhat upon the diameter of the piece and the kind of metal being spun. Excellent results may be obtained by using slower speeds without sacrificing quality. Speeds over 1800 RPM should never be attempted by the beginner because of the greater safety hazard.

Increasing the speed above 1800 RPM is sometimes accomplished in industry for the sole purpose of "stepping-up" production.

Procedure:

1. Place a properly formed chuck and follow block in position.
2. The disc or blank (aluminum or pewter about 20 gauge for beginners) is inserted between the chuck and the follow block. The blank should be large enough but not too large. No set rule for dimensions is possible. A simple method of finding the approximate disc radius is to measure with a string along the contour of the chuck, from the center of the bottom to the edge. Place enough pressure on the follow block to hold the metal disc firmly in place; do not use more pressure than is necessary. Center the disc as well as possible by eye.
3. Stand out of line with the disc, and start the lathe at a slow speed. If the disc is not too badly off center, it will revolve with the chuck and follow block. If it is too far off center, it may fly out with some force. *This is the most dangerous step in the spinning process, and caution is necessary.*
4. If the disc is running off center, hold the beveled stick as shown, so that it is in contact with the edge of the revolving disc and the tool rest. Release a little pressure from the follow block, at the same time applying a steady pressure with the back stick. This will cause the disc to center itself, after which the pressure on the follow block is brought back to normal and the tailstock clamp tightened.
5. Stop the lathe and apply a suitable lubricant to the face of the disc. Heavy grease or tallow will give good results.

FIG. 84. Holding the beveled stick. See (4) in the Spinning procedure.

6. The pointed spinning tool is held under the right arm and close to the body. It is supported on the rest and against the pin, so as to obtain the necessary pressure against the metal disc. The rest is placed out from the disc just far enough to obtain the necessary leverage, and yet leave enough room to manipulate the tool end without cramping. The side of the point is brought against the revolving disc at a point just below, and tangent to the follow block, and pressure is exerted with a *downward rolling and sliding motion.* The disc is thus forced slowly on to the chuck. It is good practice to make sure the disc is forced on or seated at the bottom of the chuck before the outer

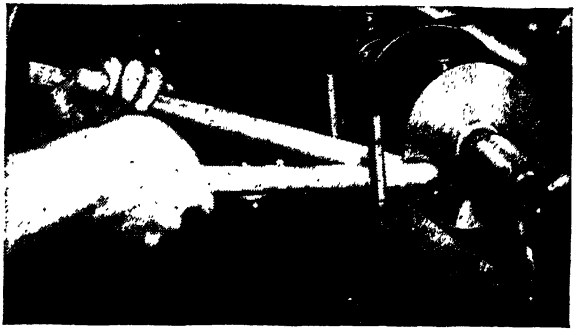


FIG. 85. Using back stick. See (6) in Spinning Procedure.

portions are touched. The disc must be forced on with long, smooth strokes, using more pressure close to the chuck and less as the disc edge is reached. Make sure that each stroke is continuous to the edge of the disc. If the disc has a tendency to wrinkle, the back stick may be used in the other hand and, supported by another fulcrum pin, to apply pressure on the other side. This backing-up action will help to prevent or will remove the wrinkles. However, with a little practice, it is entirely possible to spin the entire article with the pointed tool without wrinkles.
7. *Trimming.* This procedure is continued until the metal has been laid down firmly on the chuck up to within ½″ of the edge of the metal. Turn the edge up to approximately a right angle for trimming. Before the final edge is laid down, the disc must be cut or trimmed true to the required size. The sharpened file is used for this operation. The file should be solidly supported on the rest as near to the point

of cutting as possible. Watch out for the metal chips. It is advisable to wear goggles for this operation.

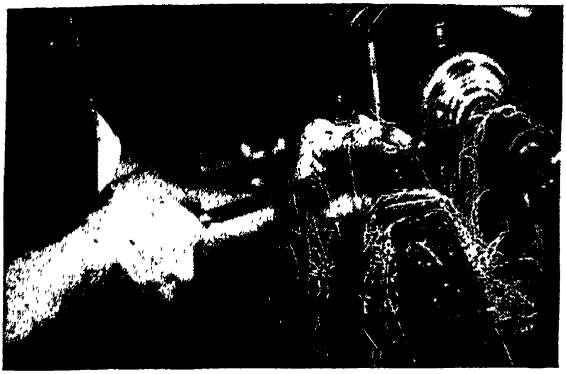


FIG. 86. Trimming with a sharpened file.

8. Now complete the spinning and polish with steel wool. A knurling tool can be used to form a decorative effect on the edge or on the outside. With a little practice, it is possible to turn a bead on the edge. In turning the bead, the trimmed edge is not laid down but with the aid of the back stick is turned over on the metal to form a closed rounded edge.

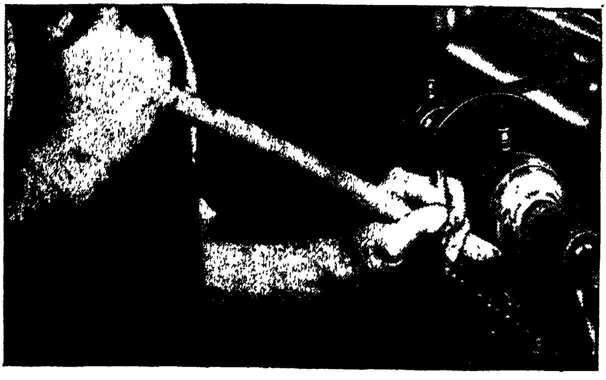


FIG. 87. Turning a bead with the backstick.

PROJECT 1

Galley Ship Plaque

This plaque makes an interesting subject for metal foil tooling.

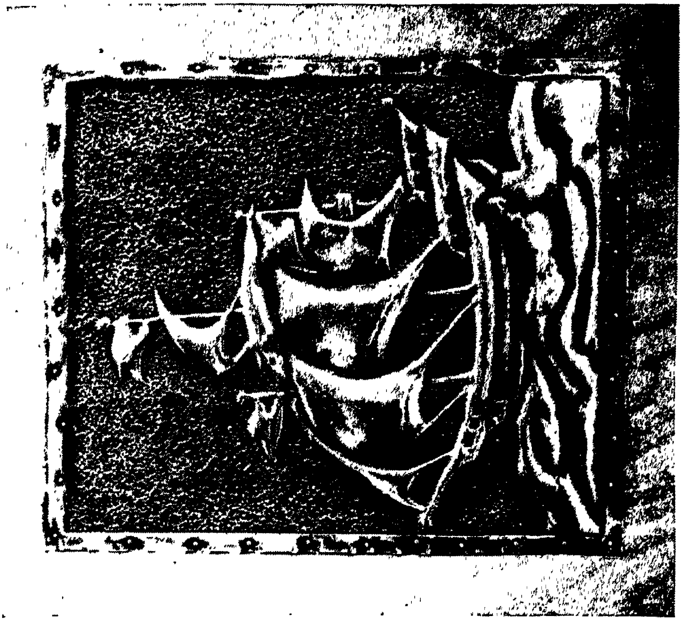
Material:

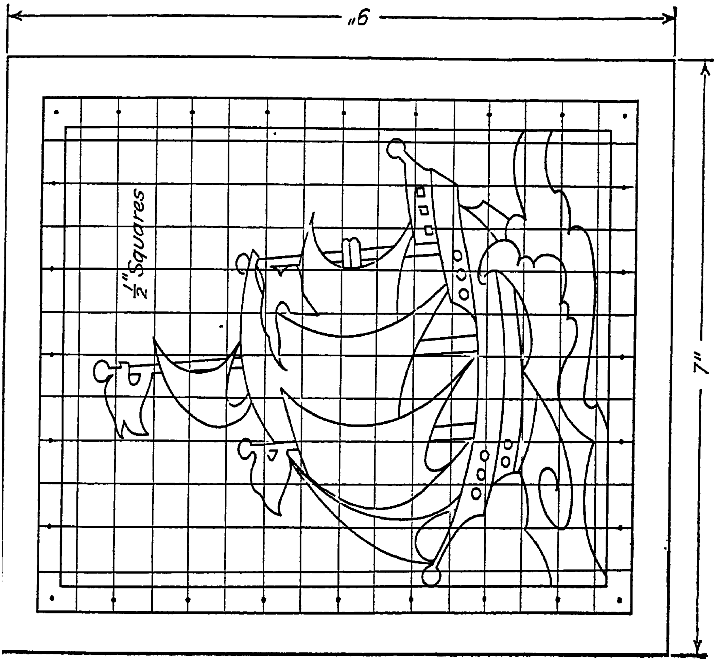
1 pc. Copper or brass foil, 32 or 34 gage, 6″ x 8″
28 3/8 #18 brass escutcheon pins
1 pc. 3/8″ plywood, 7″ x 9″

Procedure:

1. On squared paper, make a full-sized drawing of the galley ship.
2. Obtain a piece of 32 gage copper or brass 6½″ x 8½″.
3. Using carbon paper, trace the design on the copper.
4. Raise the design as explained in Chapter 3.
5. Fill raised portions with plastic fill.
6. Prepare a piece of plywood 7″ x 9″ and sand the edges.
7. Stain the wood if desired, and apply two coats of shellac.*
8. Fasten metal foil to the wood backing with escutcheon pins.
9. Clean the metal foil with very fine steel wool.
10. Lacquer or antique the surface as desired.

* See *Woodworking Crafts,* Van Tassel, R., D. Van Nostrand Co., New York, 1947.





PROJECT 1.

PROJECT 2

Bracelet

A bracelet is an excellent object for a beginner in craft work. Although the design may be pierced into the metal, the most satisfactory process of decorating the surface is by *etching*. The designs illustrated on the opposite page are suggestions for an etched design. Any of these, or any other "area type" designs which require little detail work with the brush, will be satisfactory for the beginner. The size of the bracelet blank is determined by making a stiff paper pattern and trying it on the wrist. The ends should be open enough to allow the bracelet to be removed without the necessity of bending.

Material:

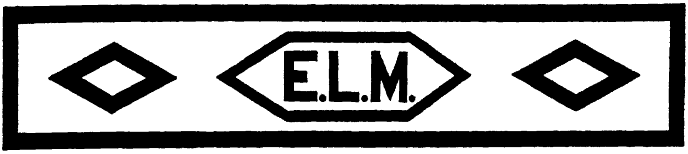
18 B & S gage hard copper, German silver, brass, or sterling silver.

Procedure:

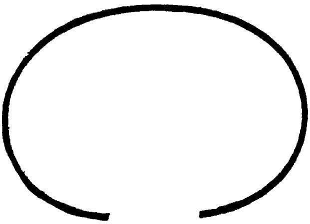
1. Make a pattern of the bracelet to determine length and width.
2. Prepare a rectangular blank the proper size.
3. Select the design to be used on the surface and trace or draw the design full-size on a piece of paper.
4. Transfer the design on to the prepared blank. (See Chapter 3).
5. Clean all surfaces with steel wool and paint the surfaces which are not to be etched with asphaltum paint. (Allow the acid resist to dry at least 12 hr.)
6. Place the bracelet blank in the etching solution and allow it to etch about $1/64''$ below the original surface.
7. When the required depth is obtained, remove the blank and rinse it in water.
8. Remove the asphaltum with turpentine.
9. If the ends of the blank are to be curved, cut the curve with *aviation snips* and smooth all edges with an 8" mill file.
10. If care has been taken in polishing the blank before it is etched, a pleasing effect is produced with no further polishing necessary. The bracelet in the illustration has been finished in this manner. If a high luster is desired, the bracelet blank is buffed. If an antique finish is desired, the surface is cleaned and the antiquing solution is applied.
11. Bend the bracelet to the shape indicated in Figure D.
12. Lacquer all surfaces unless the bracelet is made of sterling silver.

A

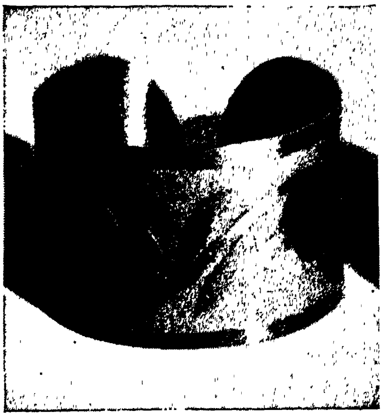
B



C



D



PROJECT 2.

PROJECT 3

Coaster

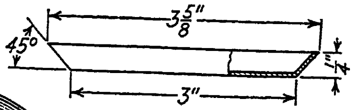
A coaster or set of coasters may be made in the metalcraft shop with a minimum amount of equipment. The special stake for forming the rim may be made by chamfering a 4″ diameter piece of cold-rolled steel or a suitable form may be made of hard wood in the wood-turning lathe. If no special stake is available, a satisfactory beveled rim may be made on a blank of metal by merely forming the bevel with a mallet over a 3″ diameter bottoming stake.

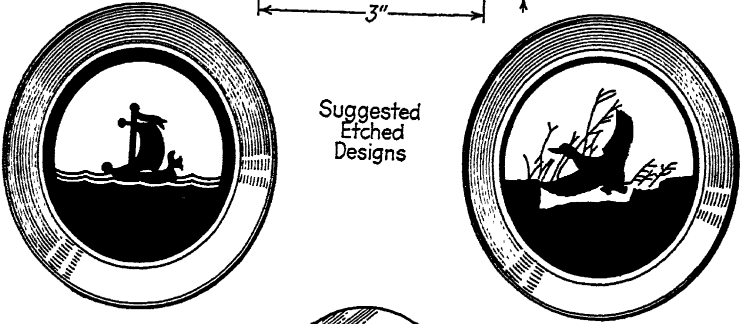
Material:

18 gage copper, brass, or aluminum 3¾″ D

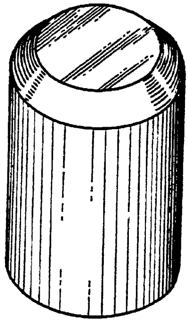
Procedure:

1. Cut out the circular disc blanks.
2. Form the bevel over the special stake or a 3″ D bottoming stake. (use a rawhide mallet.)
3. Anneal the metal if necessary.
4. Pickle the blank and clean it thoroughly with steel wool.
5. Transfer the design to be etched on the metal.
6. Paint the design with acid resist.
7. Etch the design about 1/64″ deep.
8. Clean off the resist with its solvent.
9. Mat the background with matting tools if desired.
10. Buff to a high luster.
11. Lacquer or antique the surface as desired.





Suggested Etched Designs



Special stake for use in forming beveled rim

Project 3.

PROJECT 4

Miniature Scuttle Ash Tray

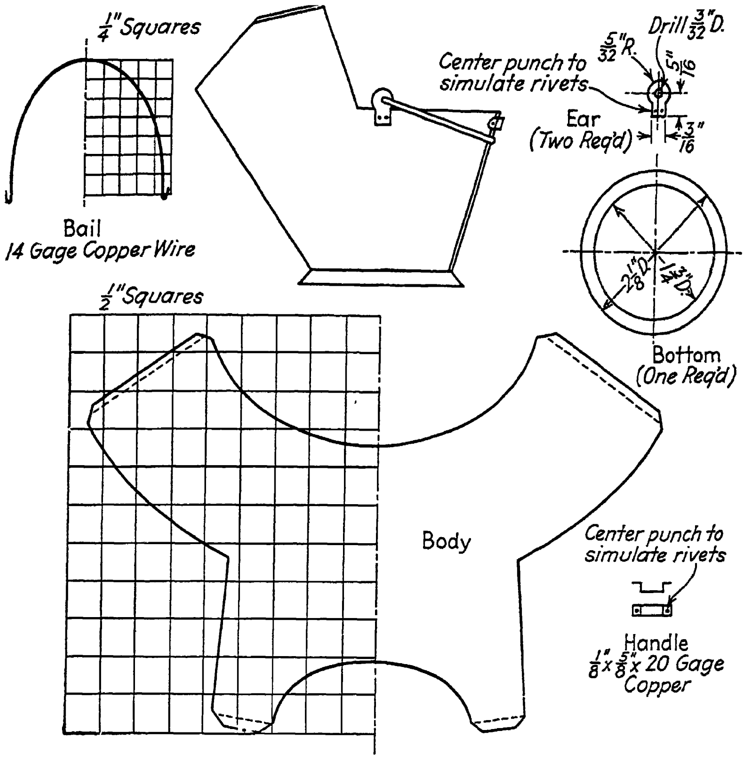
The miniature scuttle tray may be made and used for an ash tray or the pattern may be enlarged to a size 8″ or 10″ in height to be used for plants or ivy. A full-size pattern of the body should be made of stiff paper and folded into shape so that any inaccuracies in the layout may be corrected.

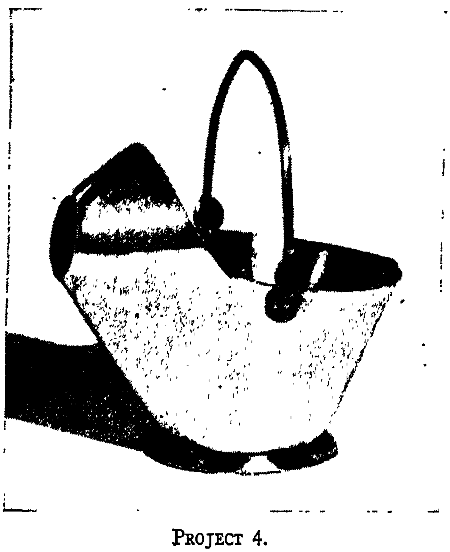
Material:

Copper or brass, 20 gage
Body: 5½″ x 9″
Bottom: 2½″ D disc
Base: Wire, #14 gage, 5½″ long
Ears and handle are made from scrap stock

Procedure:

1. Make a pattern o˙ the body and trace it on the metal with a scriber.
2. Cut out the body blank with aircraft snips.
3. Clean the surfaces with steel wool.
4. Planish or peen the surface. (This step is optional.)
5. Fold the seams for a #6 hand groover.
6. Form the body over the end of a blow horn stake.
7. Hook seams together and groove the seams with a #6 hand groover.
8. File the edges true.
9. Solder the seams with a soldering copper.
   Note: Seams may be lapped and riveted instead of using the grooved seam.
10. Cut out the 2⅛″ D disc for the bottom and flange the edge as indicated in drawing by forming it over the end of a 1¾″ D rod of steel.
11. Lay out the ears, drill a 3/32″ hole in the ears for the bail.
12. Cut out the ears with a jeweler's saw.
13. Cut a ⅛″ strip of stock for the handle and form it as indicated in drawing.
14. Wire the bottom to the body and solder it with a Bunsen burner.
15. Sweat solder the ears and handle on the body.
16. Polish all surfaces.
17. Shape the wire for bail over a stake and bend the ends to fit in the ears.
18. Finish the surfaces by lacquering or antiquing as desired.


1/4" Squares
Bail
14 Gage Copper Wire
Center punch to simulate rivets
Drill 3/32" D.
5/32" R.
5/16"
Ear
(Two Req'd)
3/16"
2 1/8" D.
1 3/4" D.
Bottom
(One Req'd)
1/2" Squares
Body
Center punch to simulate rivets
Handle
1/8" x 5/8" x 20 Gage
Copper



PROJECT 4.

PROJECT 5

Cigarette Tray

This tray is a miniature fireside log basket. It makes a good companion piece to go with the miniature scuttle ash tray previously described. By altering the size and shape slightly, the tray can be used for napkins, calling cards, or mail.

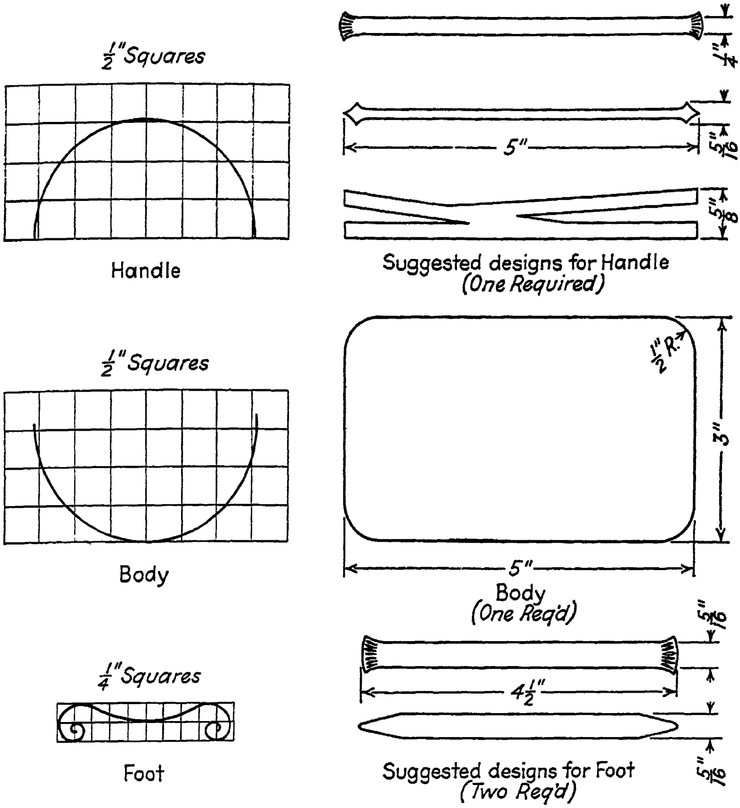
Material:

Copper or brass, 18 gage
Aluminum or pewter, 16 gage

Procedure:

1. Lay out the body blank.
2. Cut out body blank and round corners with snips.
3. File edges smooth and planish or peen the surface.
4. Form the body to shape in forming rolls or over a stake.
5. Select a design for the foot and cut out two blanks.
6. Shape the ends as suggested in the drawing.
7. Bend the ends to form a scroll using round-nose pliers.
8. Select a design for the handle and cut out a blank. Flat handles may be twisted or the handle may be made of twisted wire.
9. Bend handle to shape.
10. Tin the surfaces of the feet where they are to contact the body, clamp the feet in place on the body, and sweat-solder them in place.
11. Tin the handle at the ends, clamp it in place on the body, and solder the handle.

    Note: Handle and feet should be riveted in place instead of soldering if tray is made of aluminum.
12. Polish all surfaces.
13. Finish the surface by lacquering or antiquing as desired.


1/2" Squares
Handle
5"
1/4"
5/16"
5/8"
Suggested designs for Handle
(One Required)
1/2" Squares
Body
1/2" R.
3"
5"
Body
(One Req'd)
1/4" Squares
Foot
4 1/2"
5/16"
5/16"
Suggested designs for Foot
(Two Req'd)

PROJECT 5.

PROJECT 6

WALL POCKET

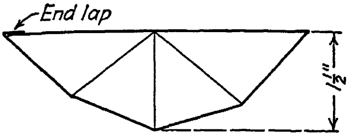
This project makes an attractive holder for ivy, flowers or trailing plants. It may be made of copper and finished in one of many attractive ways. If copper is not available, sheet iron or tin plate may be used, finishing the surfaces by painting.

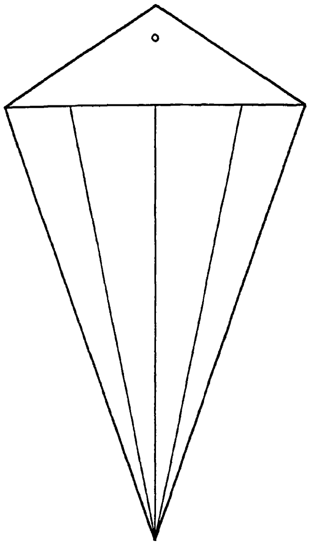
Material:

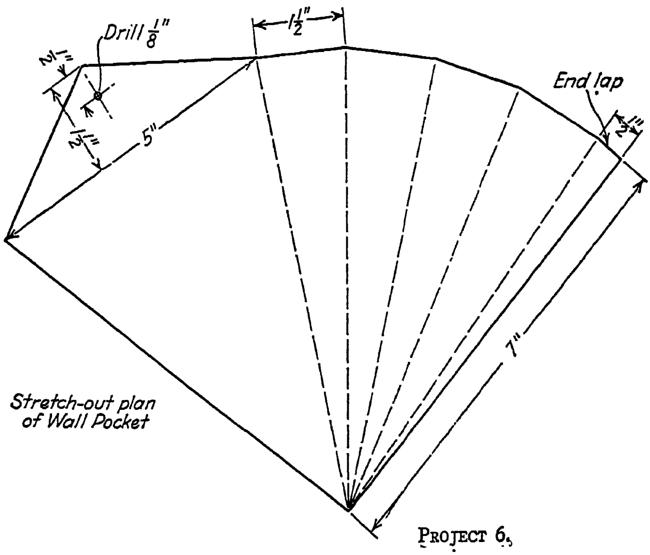
Copper, 20 gage *or* XX tin plate, 7¼" x 10½"

Procedure:

1. Cut out the material as indicated above.
2. Make a stretch-out plan of the wall pocket on a piece of paper.
3. Place the plan over the material and prick through all points with a prick punch.
4. Remove the plan and connect the points as indicated, using a scratch awl and scale.
5. Cut out the blank with tin snips.
6. Planish or peen if desired.
7. Starting with the end lap, bend folds as indicated by dotted line.
8. Fit the end lap over the back.
9. Solder the lap joint on the back.
10. Polish and lacquer or antique the surface.







Stretch-out plan of Wall Pocket

PROJECT 65

PROJECT 7

CANDLESTICKS

These candlesticks may be made singly or in pairs. They may be made all of one material or of two or three contrasting metals.

Material:

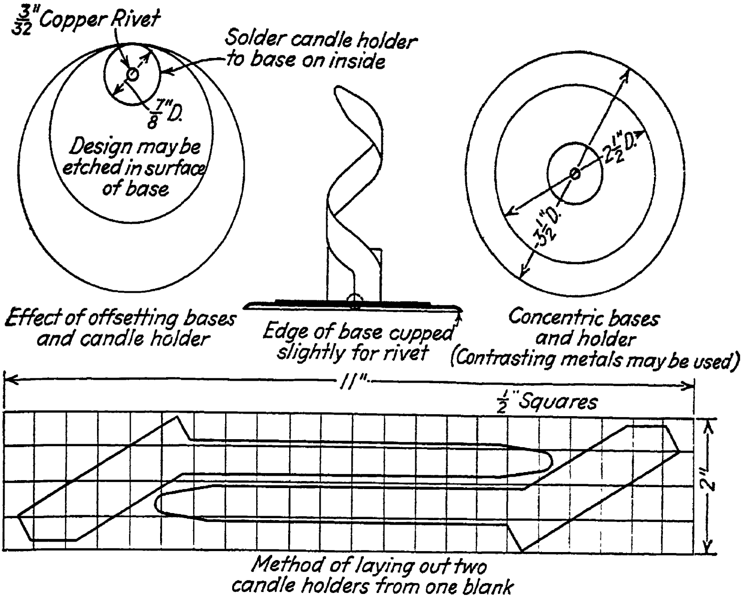
Copper, brass, German silver or pewter

Bases: 2 pc. 16 gage, 3½″ D disc
2 pc. 16 gage, 2½″ D disc

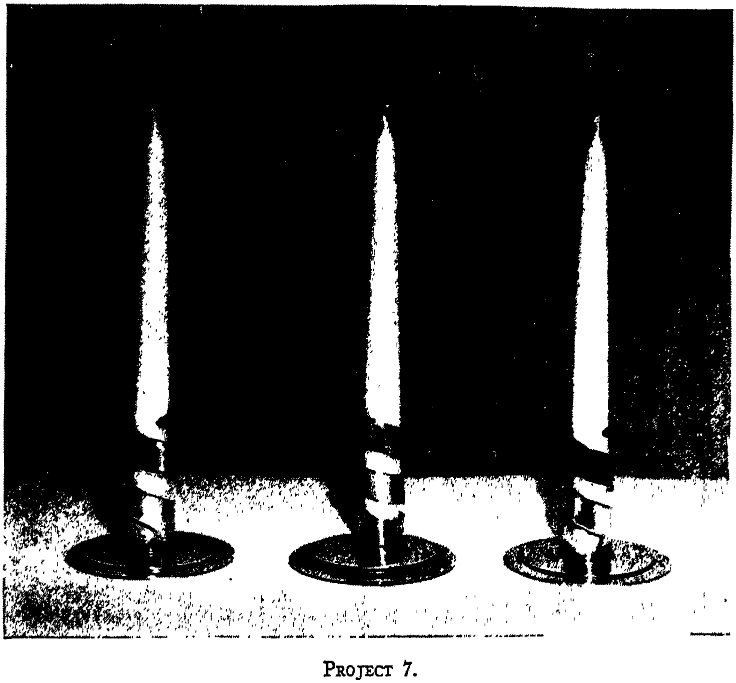
Candle Holder: 1 pc. 18 gage, 2″ x 11″
2 3/32″ x ¼″ copper rivets
2 pc. felt 3½″ D

Procedure:

1. Cut out the bases on the circular shear.
2. Cut out the blank for the holders.
3. Prepare a suitable design for etching on the surface of the base.
4. Etch the design on the base.
5. Make a paper pattern of the holders.
6. Cement the paper on the metal blank and cut out the holders with a jeweler's saw or shears.
7. File all the edges.
8. Polish, peen or planish the holder if desired.
9. Buff the holder and base pieces.
10. Form the holder around a ⅞″ dowel rod.
11. Locate the rivet hole, drill, and rivet bases.
12. Solder the holder to the bases.
13. Rebuff candlestick and lacquer.
14. Cement a felt piece on bottom of base.



$\frac{3}{32}$" Copper Rivet
Solder candle holder to base on inside
$\frac{7}{8}$" D.
Design may be etched in surface of base
Effect of offsetting bases and candle holder
Edge of base cupped slightly for rivet
$2\frac{1}{2}$" D.
$3\frac{1}{2}$" D.
Concentric bases and holder (Contrasting metals may be used)
11"
$\frac{1}{2}$" Squares
2"
Method of laying out two candle holders from one blank



PROJECT 7.

PROJECT 8

Copper Plant Box

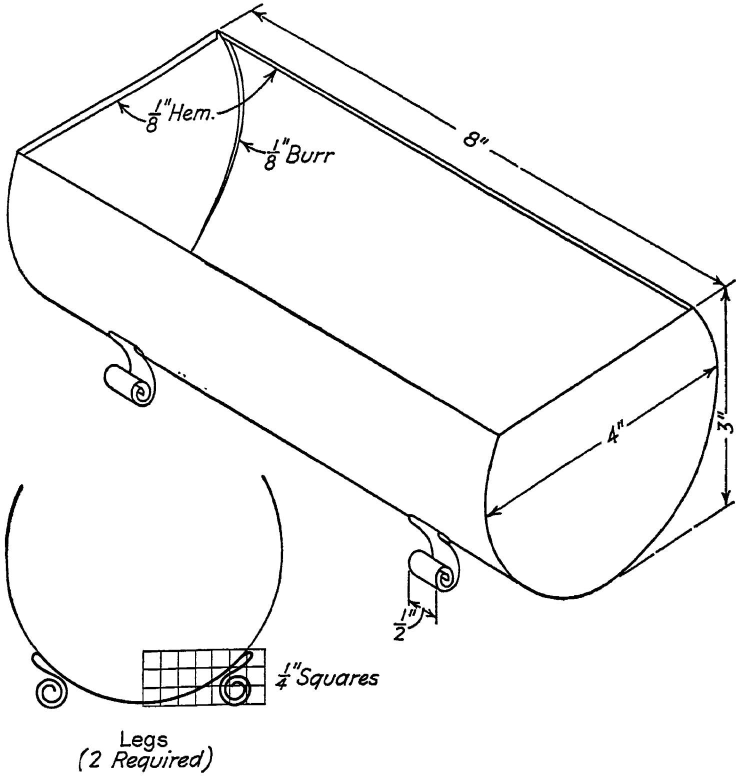
This attractive plant box is a useful item for displaying small plants such as a snake plant or philodendron. The dimensions as shown in the drawing may be changed to suit the craftsman; however it is important to maintain the original proportion if another size is desired.

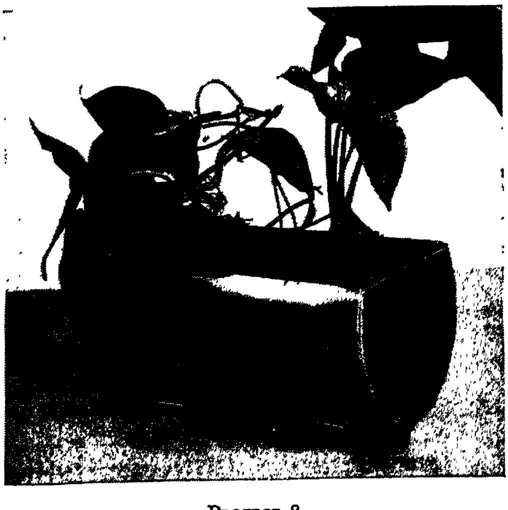
Material:

1 pc. copper, 22 gage, 8″ x 8¾″
2 pc. copper, 22 gage, 3¼″ x 4½″
2 pc. copper, 18 gage, ½″ x 8″

Procedure:

1. Cut out the material required as listed above.
2. Lay out a 4¼″ D segment of a circle on the blanks for the end pieces with dividers.
3. Cut out the segments with a pair of tin shears and turn a ⅛″ burr, as required, on the turning machine. The burr may be turned by hand over a round stake if no machine is available.
4. Fold the ⅛″ hem on the straight edge. (Corners should be notched to prevent the hem from interfering with the burr.)
5. Hem the edges of the 8″ x 8¾″ piece along the 8″ edge.
6. Form this part into a partial cylinder.
7. Assemble the pieces and bind them with binding wire.
8. Solder the seams on the inside using a soldering iron.
9. Form the ends of the legs as required using a pair of round nose plies and a stake.
10. Clean and polish all surfaces on the body and legs.
11. Tin the legs in preparation to sweat-soldering them to the body.
12. Wire the legs to the body with binding wire and sweat-solder them using a Bunsen burner.
13. Buff outside surfaces to a high luster.
14. Clean and lacquer all surfaces.





PROJECT 8.

PROJECT 9

Leaf Tray

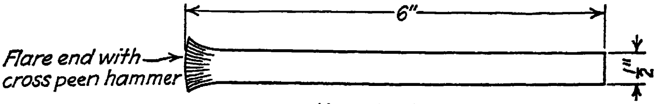
The leaf tray is an interesting project in forming an irregular shaped object over a wooden form. Variations of the suggested design may be made. When making such changes avoid the use of irregular lines or sharp curves. The tray may be used as a candy or nut dish.

Material:

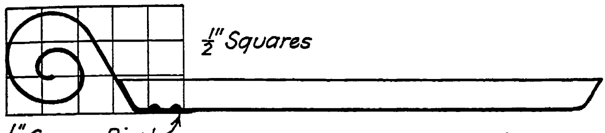
Body: 18 gage copper, aluminum or pewter, 5½″ x 8½″
Handle: 16 gage copper, aluminum or pewter, ½″ x 6″
2 rivets, $\frac{1}{16}$″ x ¼″, round-head

Procedure:

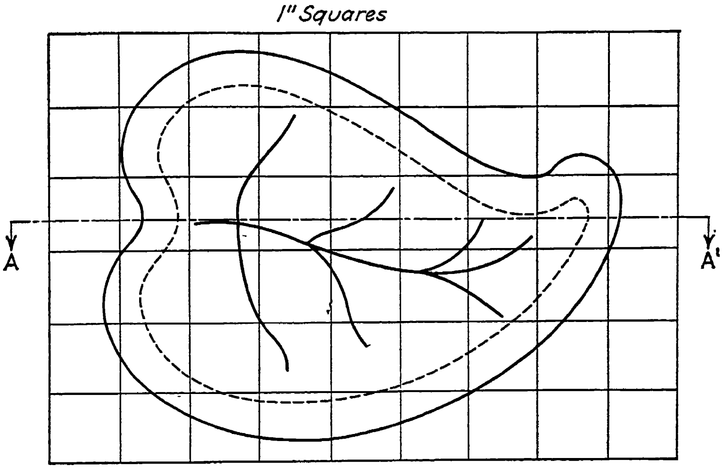
1. Make a paper pattern of the body blank (solid line).
2. Make a paper pattern of the form (dotted line).
3. Trace the body pattern on body blank and cut out the copper.
4. Trace the form pattern on a block of 1″ maple, and cut out two mold blanks.
5. With a wood rasp and cabinet file, shape one of the form blank as shown. Round all corners and sandpaper the blank smooth.
6. Peen or planish the copper blank if desired.
7. Anneal the blank and clamp the blank between the two wooden forms with "C" clamps.
8. Work the flange down onto the form, using a wedge-shaped mallet.
9. Remove the forms, pickle and clean the blank.
10. True up the edges, using a surface gage.
11. Chase the veins in leaf from the reverse side.
12. Cut out the handle blank and peen or planish the surface.
13. Flare the end of handle as suggested in drawing.
14. Form the scroll for the handle and fit it to the body.
15. Locate and drill holes for the rivets through both pieces.
16. Buff each piece separately before assembling.
17. Rivet the handle to the body.
18. Lacquer all the surfaces or antique as desired.



Handle Blank



Section of tray through A-A'



Body Blank

PROJECT 9.

PROJECT 10

ASH TRAY

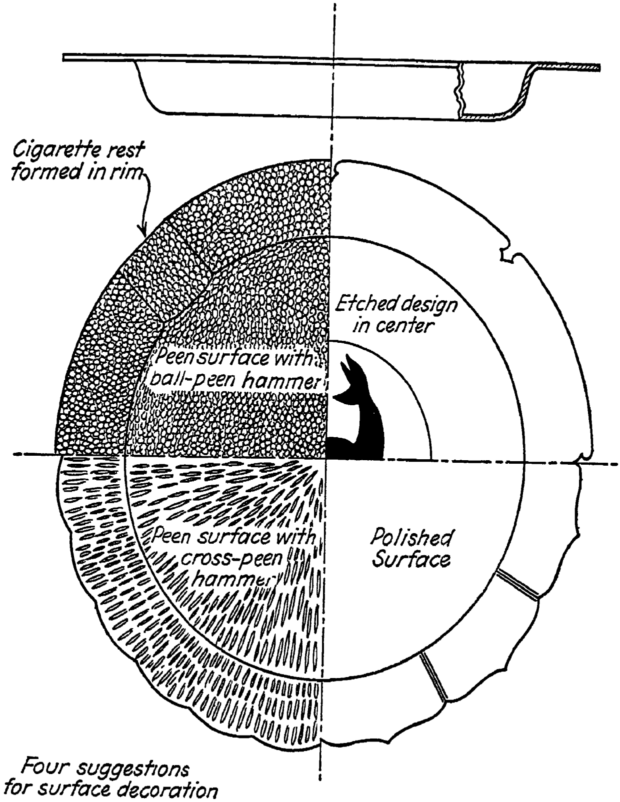
This tray may be used as a pin tray or ash tray. Many variations of surface and edge designs make it an interesting project. The size of the tray depends upon the forms which are available. If no tray form is available, one may be made on the wood-turning lathe to conform to one's own design. For instruction on wood turning, see *Woodworking Crafts* by Raymond Van Tassel.

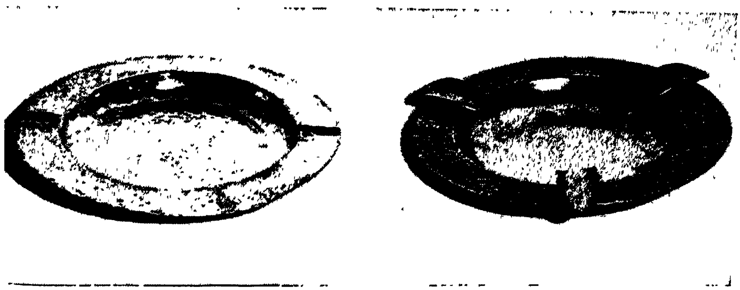
Material:

18 gage copper, brass, or pewter

Procedure:

1. Measure the recess in the tray mold and cut a disc on the circular shears to fit the recess.
2. If the surface is to be peened, peen the surface using the proper hammer and a planishing block.
3. Anneal and flatten the disc.
4. Sink the well in the tray, using the tray mold and a leather-tipped mallet.
5. Pickle and clean the surface thoroughly with steel wool.
6. True up the edge of the rim with a mill file.
7. If an edge design is to be used, make a number of equal divisions on the rim and lay out the contour of the design, using a stiff paper template.
8. Saw the edge design with a jeweler's saw and file edges.
9. Cigarette rests may be sunk in the rim using a hammer and wooden block or holders may be formed and soldered to the rim.
10. Certain edge designs are improved by fluting the rim by holding the rim on a block of wood and marking the flute with a dulled cold-chisel.
11. An etched design may be used in the center of a tray not peened.
12. Polish all surfaces.
13. Lacquer or antique as required.


Cigarette rest
formed in rim
Etched design
in center
Peen surface with
ball-peen hammer
Peen surface with
cross-peen
hammer
Polished
Surface
Four suggestions
for surface decoration



PROJECT 10.

PROJECT 11

Candy Dish

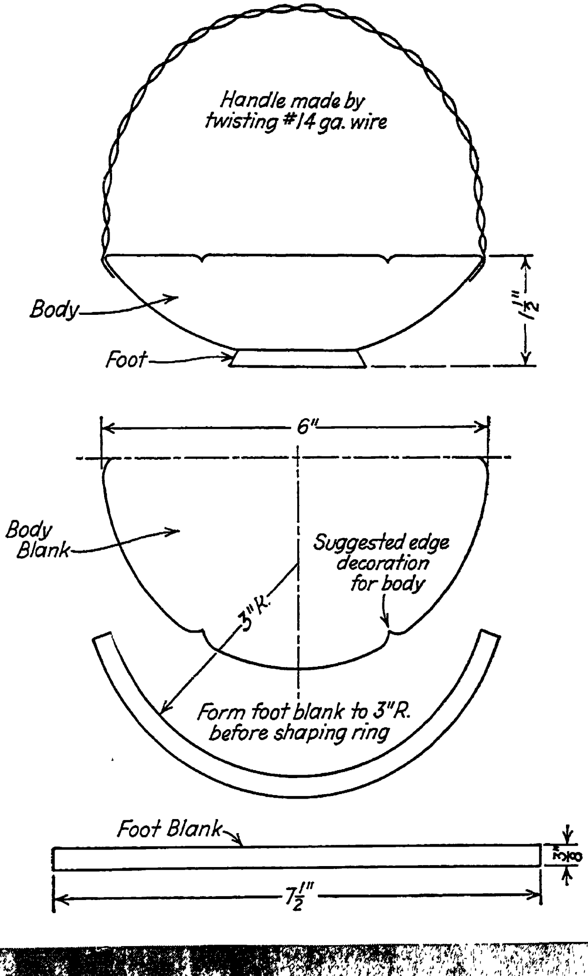
This candy dish is so shallow that it can be formed with only one annealing. Since the tray is so shallow, the usual procedure of planishing after the dish is formed is reversed and the blank is planished before forming the dish.

Material:

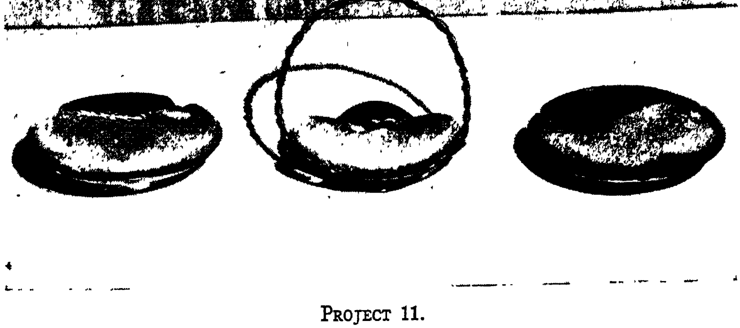
1 pc. copper, 18 gage, 6″ diameter
1 pc. copper, 16 gage, 3/8″ x 7½″
2 pc. copper wire, 14 gage, 12″ long

Procedure:

1. Cut out the material for the body.
2. Planish the surface carefully on a planishing block.
3. Anneal and pickle the blank and flatten it between two blocks of wood.
4. Mark out the divisions on the circumference of the disc, and with a template, mark out design for the edge decoration.
5. Cut out the design for the edge decoration with a jeweler's saw.
6. Cut out the material for the foot.
7. Anneal this blank and form to a 3″ radius as illustrated. Use the 6″ D body disc as a gage to test the 3″ radius.
8. Form the foot in a ring and cut and file the ends to fit.
9. Place the body blank into a spherical tray-mold and sink the blank into the mold. (A satisfactory mold can be made on the wood-turning lathe from hard wood.)
10. Pickle the body and foot and polish each with steel wool.
11. Wire the foot to the body and solder the foot to the body.
12. Clean two lengths of #14 wire for the handle.
13. Twist these wires by holding one end in the vise.
14. Cut the handle to length and flatten the ends.
15. Bend the ends of the handle to fit under the edge of the tray.
16. Sweat-solder the handle in place. (Fill foot with water to keep the foot from unsoldering while soldering the handle.)
17. Clean and buff all surfaces.
18. Lacquer the surface.



Handle made by twisting #14 ga. wire
Body
Foot
1½"
6"
Body Blank
Suggested edge decoration for body
3"R.
Form foot blank to 3"R. before shaping ring
Foot Blank
3/8"
7½"



PROJECT 11.

PROJECT 12

Fluted Bowl

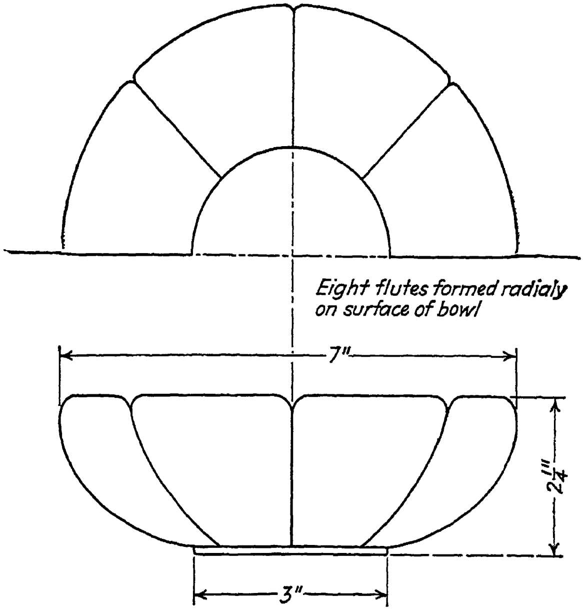
The fluted bowl is an excellent example of what may be accomplished with a flat disc by raising it on a lead or wooden block.

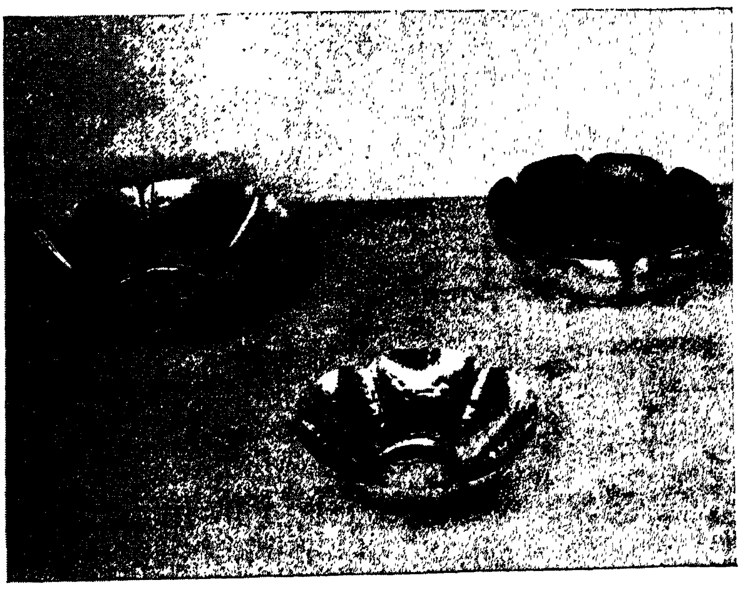
Material:

Copper, 18 gage, 9″ diameter

Procedure:

1. Cut out the disc and anneal it.
2. Raise the disc using a raising hammer and block of hard wood or lead. (See Chapter 3.)
3. Pickle the bowl and clean thoroughly with steel wool.
4. Select a planishing stake to fit the bowl and a planishing hammer.
5. Planish the outside surface.
6. Form the flat bottom with a mallet and a bottoming stake.
7. Shoulder the bottom with a necking hammer.
8. "True-up" the edge by marking the height with surface gage and trim excess stock.
9. Make eight equal divisions and draw radial lines for the flutes.
10. Prepare fluting blocks and form the flutes.
11. Scallop the edge as desired.
12. Buff all surfaces.
13. Lacquer or antique and wax the surface.





PROJECT 12.

PROJECT 13

Button Box

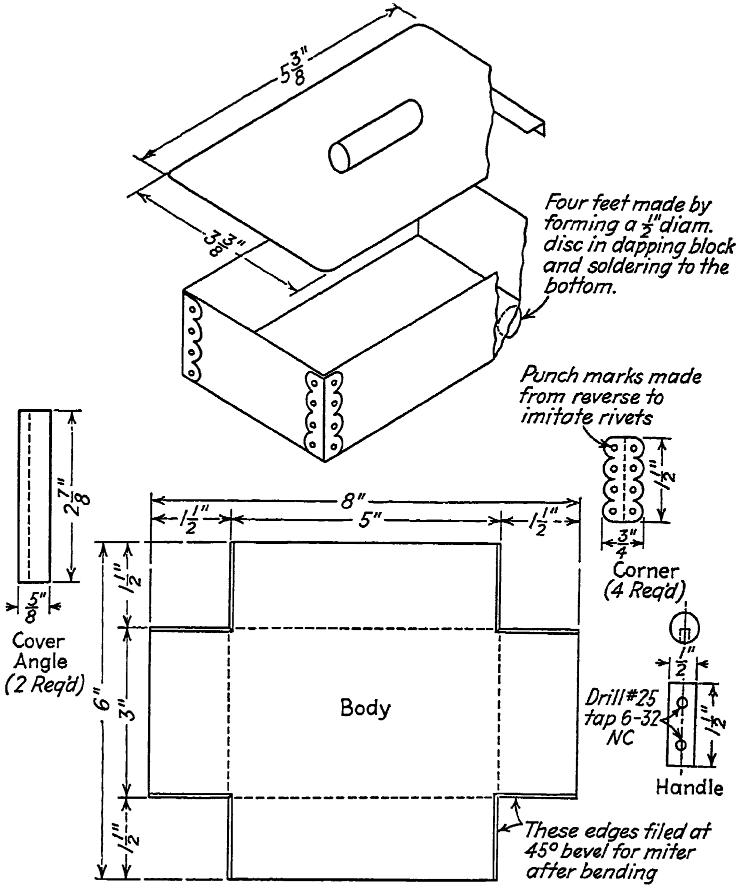
This small metal box has a number of uses. Its design may be altered to suit the taste of the craftsman. The surfaces of the top and sides lend themselves to an etched design. The cover may be left without a handle and an over-lay design may be applied.

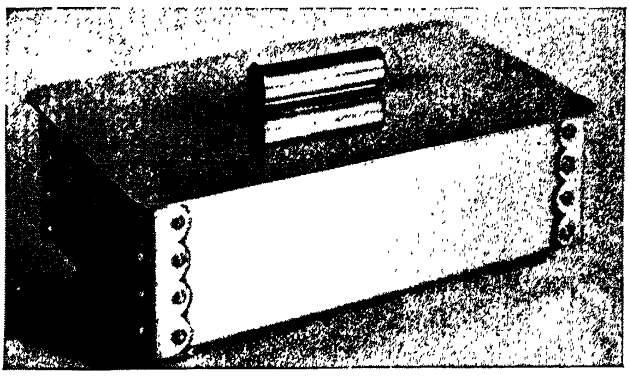
Material:

Body:	Copper, 18 gage, 6″ x 8″
Cover:	Copper, 16 gage, 3⅜ x 5⅜
Cover angle:	Copper, 18 gage, ⅝″ x 2⅞ (two required)
Corner:	Brass, 20 gage, ¾″ x 1½ (four required)
Handle:	Brass rod, ½″ D x 1½″
Feet:	Scrap copper or brass

Procedure:

1. Cut out stock for the body as required.
2. File the edges as indicated at a 45-degree angle for mitering.
3. Groove along the dotted lines with a 90-degree cold chisel in order to obtain a sharp bend.
4. Bend the body on dotted lines.
5. Cut out the corners as required.
6. Bend the corners as indicated by dotted lines.
7. Solder corner pieces on body of the box.
8. Form four dome-shaped feet and solder them to the bottom of the box.
9. Cut out the cover as required, round the corners, and file the edges.
10. Cut out the cover angles, bend as indicated, and solder them in place on the cover.
11. Cut the handle from a rod with a hack saw and file the ends.
12. Drill two 3/16″ diameter holes for the handle in the cover.
13. Drill and tap holes in handle as indicated.
14. Fasten handle to cover with two #10-24 x ¼″ round-head brass machine screws.
15. Polish all surfaces and lacquer.


5 3/8"
3 3/8"
Four feet made by forming a 1/2" diam. disc in dapping block and soldering to the bottom.
Punch marks made from reverse to imitate rivets
1 1/2"
3/4"
Corner (4 Req'd)
2 7/8"
5/8"
Cover Angle (2 Req'd)
8"
1 1/2"
5"
1 1/2"
6"
1 1/2"
3"
1 1/2"
Body
1/2"
Drill #25 tap 6-32 NC
1 1/2"
Handle
These edges filed at 45° bevel for miter after bending



Project 13.

PROJECT 14

Mail Box

This distinctive mail box will improve the attractiveness of your home and will also prove to be a practical receptical for your mail, especially those large-size cards-for-all-occasions. The fleur-de-lis designs which are pierced in the front of the box allow one to see at a glance if mail has been delivered. The sturdy rack under the box holds papers and magazines.

Material:

Brass or Copper

Part Name	*Number Required*	*B & S Gage*	*Size*
Front	1	#16	8″ x 12″
Back	1	#16	7″ x 12″
Ends	2	#16	4″ x 7″
Lid	1	#16	4¼″ x 13⅜″
Top	1	#16	⅞″ x 13⅜″
Hinges	2	#22	¾″ x 2″
Rack	1	#8 B & S or	¾″ x 17″
Rack	2	⅛″ D	¾″ x 16″
Scroll	2	#8 B & S Wire	12″ long

Procedure:

Front

1. Prepare the blank 8″ x 12″ x 16 gage by cutting with a squaring shear.
2. Locate the fleur-de-lis designs and mark them on the blank in preparation for sawing.
3. Drill a hole within the area to be pierced for the insertion of the jeweler's saw blade.
4. Insert the jeweler's saw and cut out the three designs.
5. File any irregularities on the edge of the pierced designs.
6. Form the front to the shape shown in the side view of the drawing. Use the forming roll for this operation. Form the shape slowly and compare the shape to the drawing from time to time.

Back

1. Cut the back blank 7″ x 12″ x 16 gage using the squaring shear.

Ends

1. Cut two pieces 4″ x 7″ x 16 gage using the squaring shear.

2. Lay out the oblique cut for the top of each end piece as shown in the end view of the drawing.
3. Make this oblique cut on each piece using the squaring shear.
4. Using the formed edge of the front piece as a guide, mark out the curve for each end piece with a scriber.
5. Cut this curved edge with a jeweler's saw. Saw about $\frac{1}{16}''$ outside the layout line.

Top and Lid

1. Cut blanks for the top and lid $\frac{7}{8}''$ x $13\frac{3}{8}''$ x 16 gage and $4\frac{1}{4}''$ x $13\frac{3}{8}''$ x 16 gage using the squaring shear.
2. Lay out the 1″ R scalloped edge as indicated in the drawing.
3. Cut the scallops in the edges using a jeweler's saw.
4. Fold the edges using wooden blocks in a vise or a bar folder.
5. File the edges to remove any burrs.

Scroll

1. Cut two pieces of #8 gage copper wire 6″ long.
2. Bend the scrolls as shown in the front view using a bending jig.

Rack

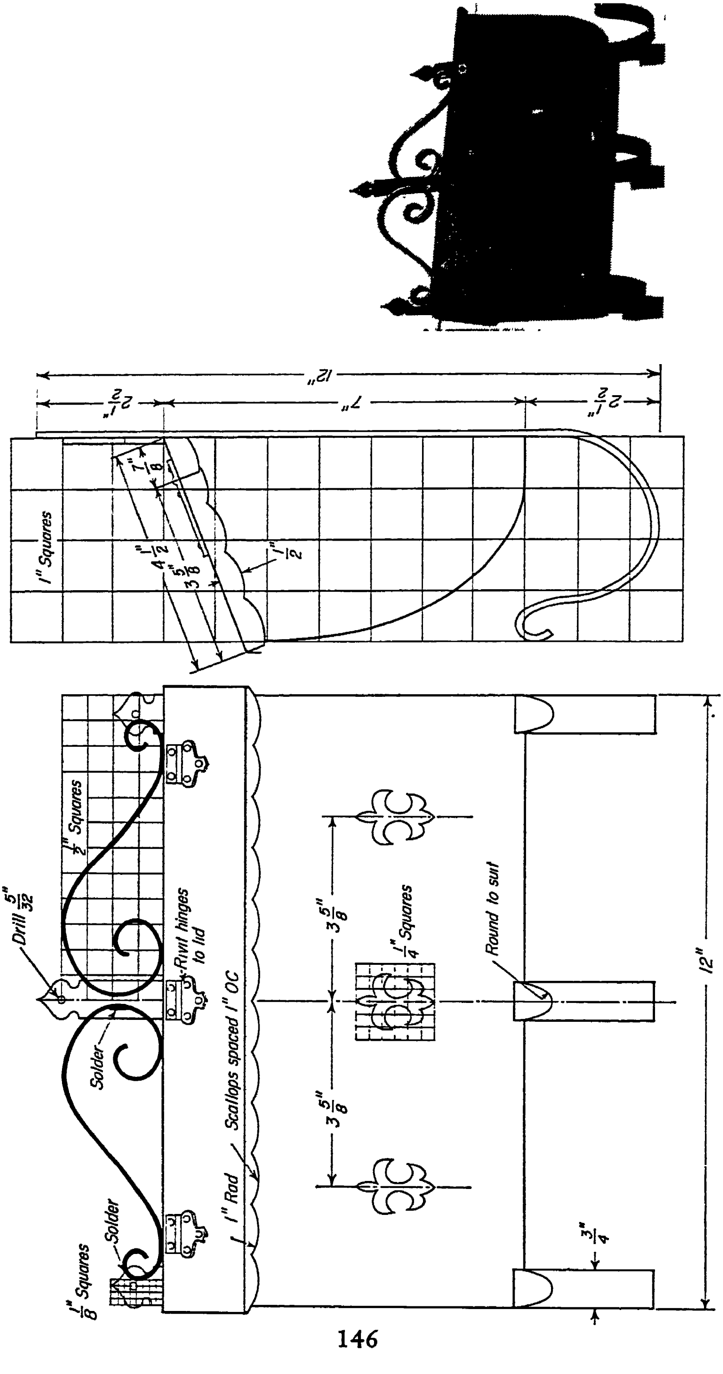
1. Cut three pieces for the rack as indicated.
2. Lay out the design on the ends of each piece.
3. Cut these designs using a jeweler's saw.
4. Form the contour on each piece by bending the pieces in a bending jig. (See the end view of the drawing).
5. Drill a $\frac{5}{32}''$ hole in the top of each rack piece for a screw.

Hinges

Suitable hinges may be purchased for the lid, or hinges of your own design may be made from 22 gage metal.

Assembly

1. Solder the ends and back on the inside of the box using a large soldering copper or a propane torch.
2. Solder the top along the back edge and ends.
3. File off excess material along the soldered edges and ends.
4. Fasten the lid to the top with hinges. Copper rivets would be suitable for this purpose.
5. Solder the rack pieces to the back and adjust the bottom contou of each rack piece to match.
6. Solder the scroll pieces in place.
7. Polish all surfaces.
8. Coat all surfaces with two coats of lacquer.


1" Squares
12"
2 1/2"
7"
2 1/2"
7/8"
4 1/2"
3 5/8"
1/2"
Drill 5/32"
1/2" Squares
Rivit hinges to lid
Solder
Solder
1/8" Squares
1" Rod
Scallops spaced 1" OC
3 5/8"
3 5/8"
1/4" Squares
Round to suit
3/4"
12"

PROJECT 15

Cast Book Ends

Any book end, which has already been cast, may be used as a pattern for this useful project. When selecting a model suitable for a casting, observe whether or not there is sufficient draft so that the pattern may be easily withdrawn from the mold. A hole may be drilled and tapped in the back of the pattern near the center of gravity, in order to insert a machine screw to be used as a lifter.

Material:

Zinc alloy or pewter scrap
Piece of felt for the base

Procedure:

1. Select a suitable pattern for the book end.
2. Ram up a mold of the pattern selected. (See "Molding Procedure" in Chapter 3.)
3. Pour the molten metal in the mold.
4. Allow the casting to cool, break up the mold and remove the sprues with a hack saw.
5. Ram up and cast a second book end.
6. File the irregularities on the edges.
7. Polish the surface with buffing wheel.
8. Cut and cement a piece of felt to the base.
9. Clean all surfaces and lacquer if desired.

PROJECT 16

Mosaic Tile Tray

Here is an attractive mosaic tile tray that has a number of uses around the home. It is especially useful as a hot plate for protecting counter surfaces in the kitchen or the surface of a serving table in the dining room. The metal components for the tray are easily made and may be made in many sizes and shapes. The arrangement of the tiles gives the craftsman the opportunity to express himself in design. The colors in the tray illustrated were two shades of gray with ivory, buff, and brown tiles used to produce the design.

Material:

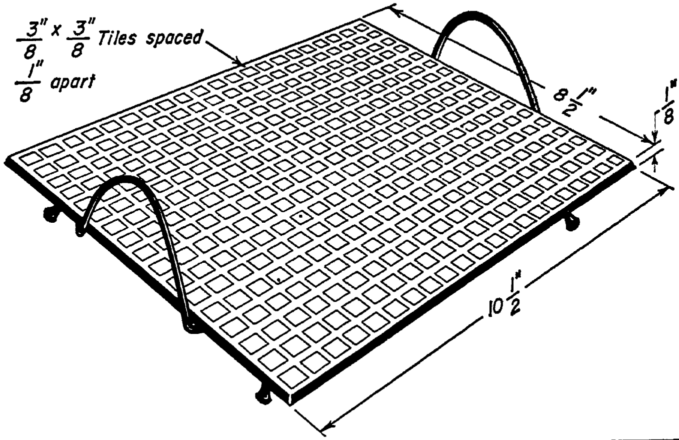
1 pc.	18 ga. copper	8⅝″ x 10⅝″
2 pc.	4 ga. copper wire	10″ long
357	mosaic tile	⅜″ x ⅜″
1 pkg.	patching plaster	
4	rubber feet	3/16″ D

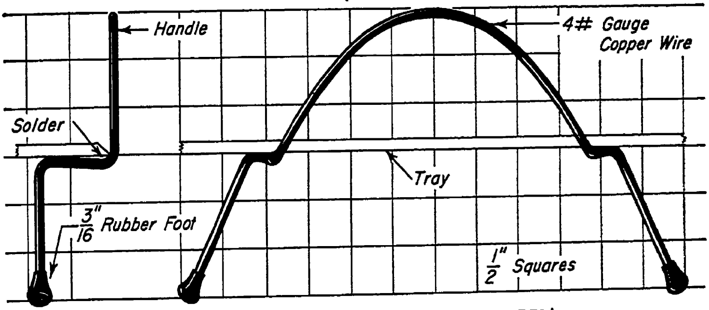
Procedure:

1. Mark off a series of ½″ squares on a piece of brown wrapping paper 8½″ x 10½″.
2. Plan the design for the tiles by indicating the various colors of the tiles in each square.
3. Cement each tile face down on the paper using a liquid glue. Arrange the tiles so that there is an even border around each.
4. While the glue is drying, check the over-all dimension of the prepared tile design and cut a piece of 18 ga. copper ⅜″ more than the measurement of the tile in each direction.
5. Notch the four corners of this piece ⅜″ x 45 ° in preparation for folding.
6. Fold the edges of the tray to form a ⅛″ edge. Use the bar folder or a brake for this fold. If none is available, the edge may be folded by clamping the stock between two blocks of wood.
7. File the edges.
8. Form the handles from #4 copper wire.
9. Solder the wire handles in place.
10. Polish and lacquer the metal surfaces.
11. Cement the tile design in place with patching plaster or a special commercial preparation for cementing tiles.
12. After the tile cement has hardened, remove the brown paper after wetting with water.

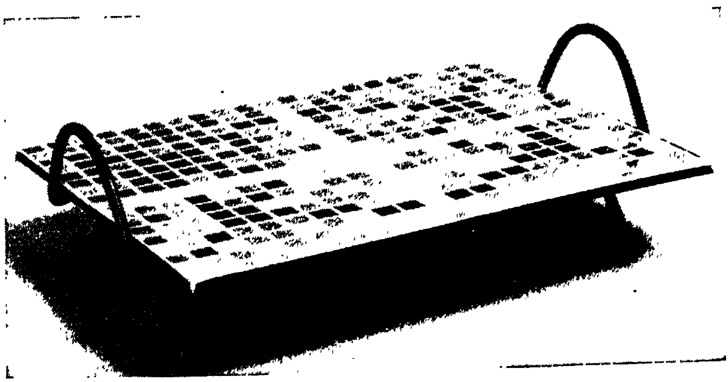
13. Fill in the cracks between tiles with additional tile cement where needed.

14. Fit each foot with a 3/16″ rubber foot to keep the tray from scratching the surface upon which it is used.





DETAIL FOR WIRE HANDLES (TWO REQUIRED)



PROJECT 15.

PROJECT 17

Plant Stand

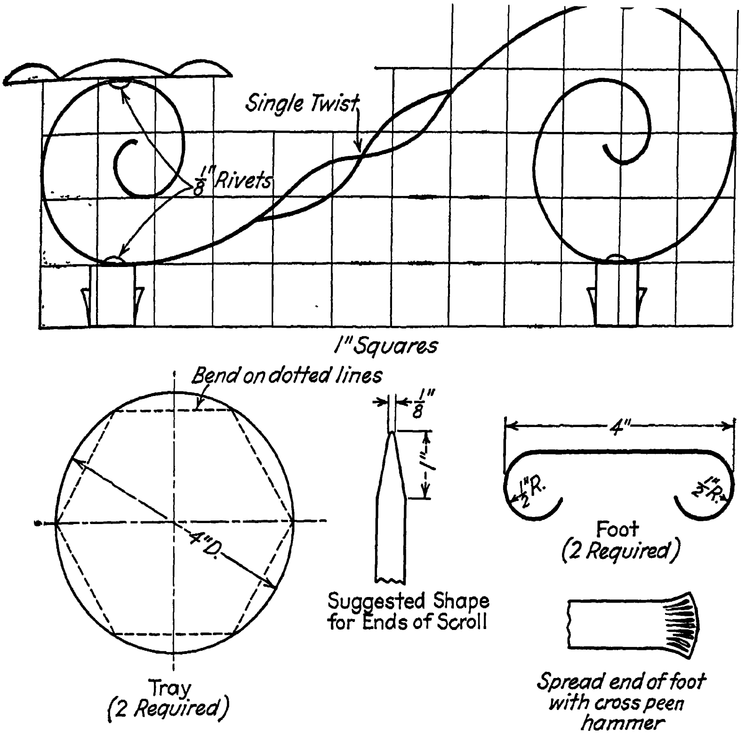
This plant stand will hold two small pots of ivy. An attractive arrangement may be made with two of these stands on a library table.

Material:

Scroll:	1	pc.	band iron, $\frac{1}{8}'' \times \frac{1}{2}'' \times 30''$
Foot:	2	pc.	band iron, $\frac{1}{8}'' \times \frac{3}{4}'' \times 7''$
Tray:	2	pc.	copper or aluminum 18 gage, 4″ D
Rivets:	4		round-head, iron, $\frac{1}{8} \times \frac{1}{4}$

Procedure:

1. Make a full-size layout of the scroll and feet on heavy paper.
2. Cut out material as indicated.
3. Lay out and shape the ends of the scroll piece to the suggested contour on the drawing.
4. Spread end of foot blanks on the anvil, using cross-peen hammer.
5. Bend the scroll in a bending jig beginning at each end and working toward the center.
6. Make a twist in the scroll as indicated on the drawing.
7. Bend the feet to shape over 1″ D steel rod held in a vise.
8. Lay out a hexagon on the 4″ D copper discs.
9. Fold the edges of the tray as indicated, using wooden blocks in a vise or the bar folder.
10. Locate and drill the holes for rivets.
11. Polish the trays and antique their surface if desired.
12. Rivet the trays and feet in place. *Note*: The natural oxidized finish on the band iron protects its surface from rusting and also leaves a pleasing dull finish; therefore, no additional finish is necessary.


Single Twist
1/8" Rivets
1" Squares
Bend on dotted lines
4" D.
Tray
(2 Required)
1/8"
1"
Suggested Shape
for Ends of Scroll
4"
1/2" R.
1/2" R.
Foot
(2 Required)
Spread end of foot
with cross peen
hammer

PROJECT 16.

PROJECT 18

Ship-Shape Candle Sconce

This replica of an early American ship candlestick stays in a vertical position when the base is resting on a table or when hung on a wall. Made of solid brass, this candlestick serves as an attractive accessory for early American furnishings. A pair of them may be used on a mantel or hung on the wall on each side of a doorway or chimney. An interesting effect in constrasting metals may be obtained by making some of the parts from copper.

Material:

Part name	*Material*	*Number required*	*B&S Gauge*	*Size*
Base	Spinning Brass or Copper	1	22	6″ D
Harp	Brass or Copper	1		$\frac{3}{32}$″ x ½″ x 15″
Candle Stick	Brass	1		1½ D x 5⅞″
Finger Grip	Brass	1		¼″ x 2″ x 2½″
Ring for Hanging	Brass	1	18 Wire	1¼″

Procedure:

Base

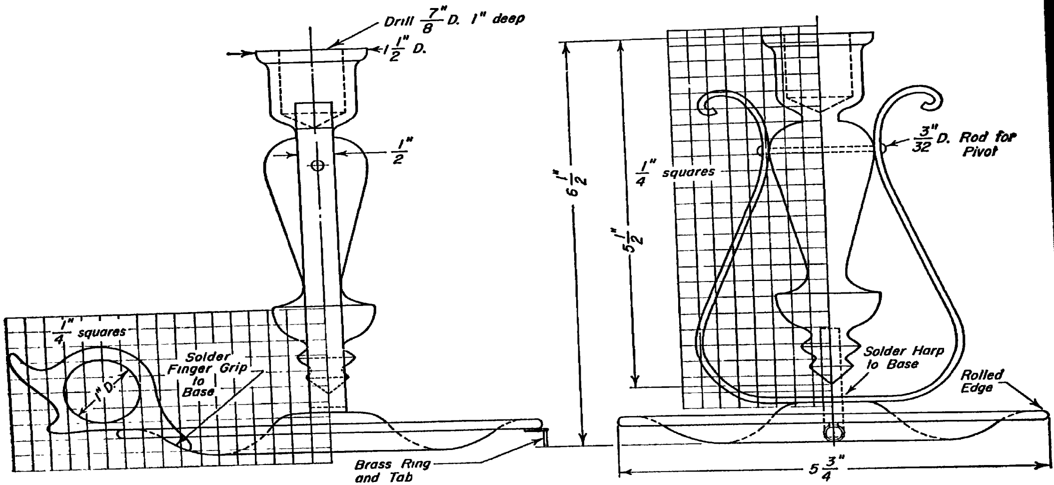
1. Prepare a circular disc of 22 gauge spinning brass or copper six inches in diameter.
2. Prepare a spinning chuck of the shape indicated in the drawing.
3. Spin the disc to the shape of the spinning chuck.
4. Trim the outer edge and form the rolled edge.

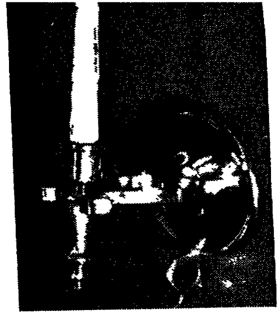
Harp

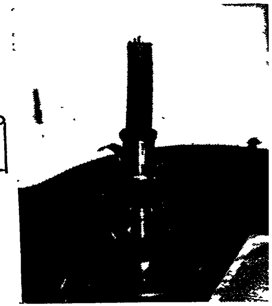
1. Cut a 15″ length of $\frac{3}{32}$″ x ½″ brass or copper with a hack saw.
2. Shape the ends of this piece with a file as desired.
3. Make a full-size layout of the shape of the harp.
4. Bend the harp to shape using a bending jig.

Candle Stick

The candle stick is to be turned on a wood lathe using hand tools much in the manner of wood turning. If a metal lathe is available, the candle stick may be "roughed out" with metal cutting tools and then finished







PROJECT 18. Ship-shape candle sconce.

PROJECT 19

Miniature Anvil Paper Weight

This project is a popular novelty for the metalcrafter who wishes to familiarize himself with the art of sand casting. In order to make the paper weight, a wooden pattern must be available. The pattern may be made by an amateur by following the directions given here and referring to *Woodworking Crafts* by Raymond Van Tassel. Once the pattern is made, an indefinite number of castings may be produced from the one casting.

Anvil Pattern

Material:

2 pc. white pine or mahogany, ¾″ x 1½″ x 4″

Procedure:

1. Obtain the stock and sandpaper one surface on each piece by placing a large piece of #½ sandpaper on a flat surface and moving the block over the sandpaper in the direction of its grain.
2. Locate the ⅛″ holes for the dowel pins.
3. Place the pieces face to face and drill the ⅛″ holes through one piece and 3/16″ deep in the second piece.
4. Glue dowel pins in piece #1 allowing them to be loose in the second piece.
5. With the pieces together, make a layout of the anvil on the face and end and saw away excess stock with a coping saw.
6. With a knife and file, shape the pattern as shown in drawing.
7. Make sure all surfaces taper slightly away from the center or *parting line* of the pattern. This taper is called *draft* and allows the pattern to be removed from the stand without disturbing the mold.
8. Sandpaper and apply two coats of shellac to all outside surfaces.
9. Sand pins so that the pieces are easily separated.

Casting

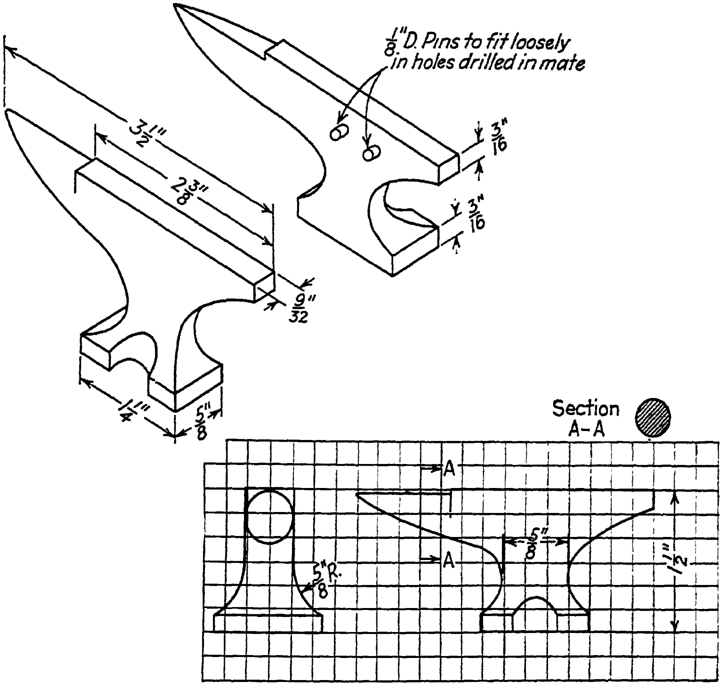
Material:

Pewter scrap, zinc alloy or aluminum.

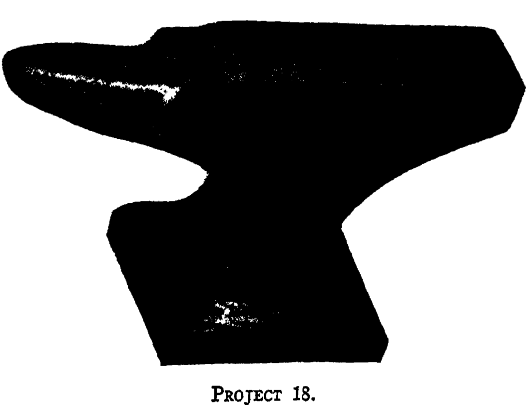
Procedure:

1. Ram up a mold of the above pattern. (See "Molding Procedure" in Chapter 3.)
2. Pour the molten metal in the mold.

3. Allow the casting to cool, break up the mold and remove the sprues with a hack saw.
4. Clean the casting with a file.
5. Polish the casting with abrasive cloth.
6. Buff and lacquer all surfaces.



1/4" Squares



PROJECT 18.

PROJECT 20

Spun Nut Dish

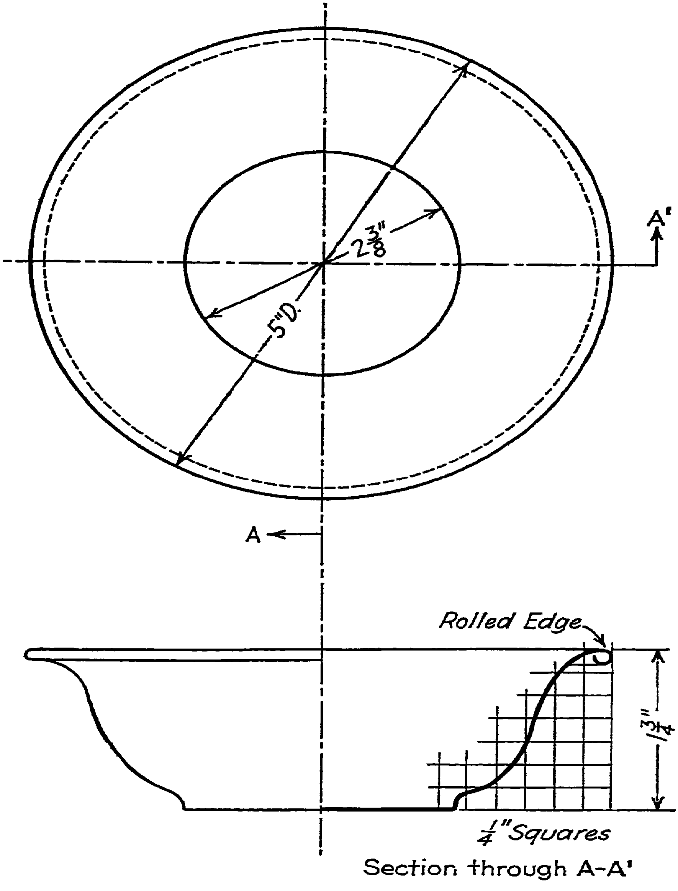
A dish of this type or one which is a little more shallow is a good beginning project for metal spinning. Pewter is an excellent medium for metal spinning because it requires no annealing while it is being worked over the form; however, for practice, it is suggested that the beginner spin one or two practice pieces of aluminum in order to learn the technique.

Material:

20 gage pewter, 7″ diameter

Procedure:

1. Turn a chuck for the dish from a block of maple.
2. Cut a disc of pewter, 7″ diameter.
3. Mount the disc on the chuck in the spinning lathe.
4. Center and lubricate the disc.
5. Spin the disc over the chuck.
6. Trim the upper edge of the dish.
7. Roll the edge as indicated in the drawing.
8. Remove the dish from the lathe and polish it with fine steel wool.
9. Buff and wax the surface.


A'
$2\frac{3}{8}$"
5"D.
A
Rolled Edge
$1\frac{3}{4}$"
$\frac{1}{4}$" Squares
Section through A-A'

PROJECT 20.

PROJECT 21

Powder Box

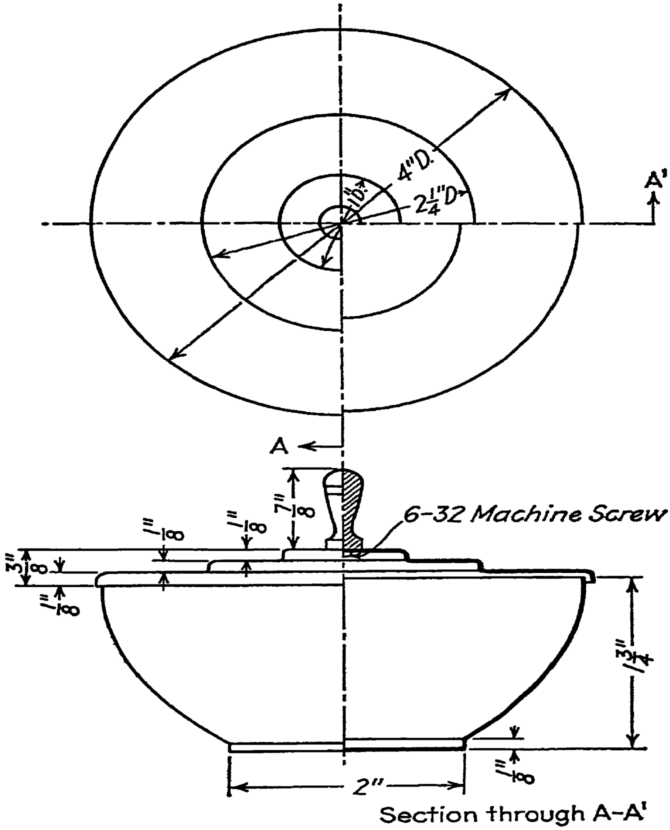
This powder box can be made of pewter or the base may be made of copper and the cover in brass. The knob may be made of brass or pewter rod or, if plastic rod is available, a contrasting color may produce a pleasing effect. After the chuck has been turned, it would be a good plan to spin a trial piece of aluminum before the more expensive metals are used.

Material:

1 pc. pewter or copper, 20 gage, 6½″ D
1 pc. pewter or brass, 20 gage, 4½″ D
1 pc. brass, pewter, or plastic rod, ⅜ D x ⅞″
1 Round-head brass machine screw, 6-32 x ¼″

Procedure:

1. Prepare the chuck for the cover according to the dimensions suggested in the drawing.
2. Prepare the disc for the cover.
3. Mount the disc on the chuck in the spinning lathe.
4. Center and lubricate the disc.
5. Spin the disc over the chuck.
6. Trim the edge according to the dimensions in the drawing.
7. Polish lightly with fine steel wool.
8. Repeat the above steps in making the base for the box.
9. Cut a 2″ length of ⅜″ rod and chuck it in the headstock of a wood or metal turning lathe.
10. Turn the rod to the shape of the knob, using a round-nose tool.
11. Drill a hole in the center of the end of the knob with a #38 drill.
12. Tap a thread in this hole with a 6-32 tap.
13. Drill a hole in the center of the cover with a #28 drill.
14. Polish the inside of the box with fine steel wool.
15. Buff the exterior surfaces.
16. Assemble the cover and knob.
17. Lacquer or wax as desired.


4"D.
$2\frac{1}{4}$"D.
$1\frac{1}{8}$"
A'
A
$\frac{7}{8}$"
6-32 Machine Screw
$\frac{1}{8}$"
$\frac{1}{8}$"
$\frac{3}{8}$"
$\frac{1}{8}$"
$1\frac{3}{4}$"
$\frac{1}{8}$"
2"
Section through A-A'

Project 21.

PROJECT 22

Vanity Box

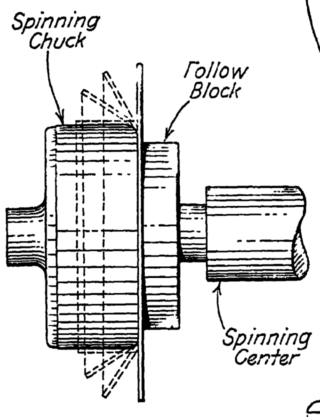
An interesting exercise in metal spinning is incorporated in this project. At first glance the box appears to be one piece; the soldered seam at the base is not visible. The body of the box is spun first and then a hole 3½ inches in diameter is trimmed to receive the cover. The bottom disc is soldered on this piece to form the box. The cover may be made of plastic or wood by turning it on the wood turning lathe. The knob may be made from the scrap pewter by melting and casting it into a rod and then turning it to shape in a lathe.

Material:

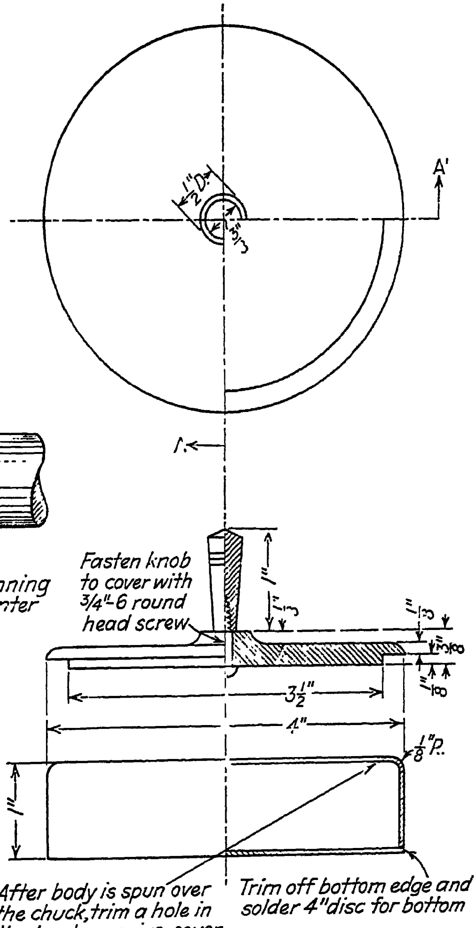
1 pc. 18 gage pewter 6″ D
1 pc. 18 gage pewter 4″ D
1 pc. hardwood or plastic ⅜″ x 4″ D
1 ¾″ #6 round-head wood screw

Procedure:

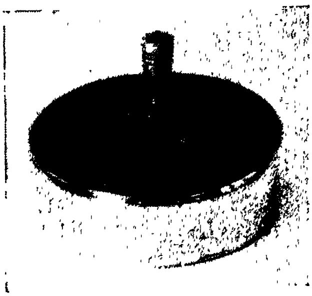
1. Prepare a spinning chuck and follow block as indicated by dimensions in the drawing.
2. Cut out the disc for the body.
3. Mount the disc on the spinning chuck in the spinning lathe.
4. Center and lubricate the disc.
5. Spin the disc over the chuck.
6. Trim off the bottom edge.
7. Trim a hole in the top of the box to receive the cover.
8. Remove the body from the chuck.
9. Prepare a 4″ diameter disc for the bottom.
10. Solder this disc onto the bottom.
11. File the edge flush with the body and polish.
12. Turn the cover to fit the body.
13. Prepare a blank for the knob by pouring molten pewter into a 9/16″ diameter hole drilled in the end of a piece of wood.
14. Place this blank in a chuck in a wood or metal turning lathe.
15. Turn the knob to the desired shape using wood turning tools.
16. Drill a hole in the cover and knob to receive a #6 wood screw and fasten the knob to the cover with a ¾ #6 round head wood screw.
17. Clean the inside of the box with fine steel wool.
18. Buff all exterior surfaces.
19. Wax all surfaces.



Method of Spinning Box



Section through A-A'



Project 22.

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